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Group 4

CONTROL SYSTEMS LABORATORY

A SHORT DESCRIPTION OF THE
JNS CONTROL PROGRAM

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Report R-88

A SHORT DESCRIPTION OF THE JNS CONTROL PROGRAM

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URBANA, ILLINOIS
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Preface

Early in 1956 this laboratory published a report, R-74, by J. N. Snyder and L. D. Fosdick "On the Use of a High Speed General Purpose Digital Computer as the Control Element in a Surveillance and Control System". It stands as a comprehensive text discussing all the detailed actions of the control program designed by J. N. Snyder and all the considerations which entered into that design.

For those people both inside and outside the Control Systems Laboratory who do not require a complete knowledge of the Snyder Control Program, this smaller R-88 is offered by the present author. It is intended to provide a brief description of the control program and to serve as an abbreviated handbook for some of the control personnel.

Introduction

The original detailed proposal for the design of "An Automatic Air Traffic Information and Control System" (R-35, by A. T. Nordsieck, 1953), of which Cornfield is a research model, included, as its title promised, not merely a discussion of facilities for automatic surveillance, but also for control. It was suggested at that time that, in such a system, a control computer might perform many useful functions including threat evaluation, weapons assignment, and steering calculations for friendly aircraft. Considerations of radar data input rate to the system and communication bandwidth requirements within the system showed advantages in the sharing of logical and computational functions by three different types of computers instead of being performed within a single large multi- or general-purpose facility. Two of these types are special purpose machines: one for high speed data processing, the other for automatic tracking, association and storage of ancillary data, and clear picture generation. Taken together with their associated radars and communication and display equipments they perform the surveillance functions of the Cornfield System. The control functions are handled by the third type of computer and are the subject of this text.

In the summer of 1955 J. N. Snyder of this laboratory undertook "to investigate whether or not the complex logical and decision making functions involved in the overall control program can be formulated in such a way as to lie within the capabilities of automatic general purpose digital computers; if this be possible, to determine what fraction of the task can be carried out by a computer of known speed and capacity, (specifically) Illiac." The problem was considered to be that of formulating a number of rules sufficient to carry out the logical processes of control, and formalizing them in a program for Illiac. The success of the investigator was to be measured by whether control decisions could be so formalized and, secondarily, the degree of completeness with which such a formalization would lie within the speed and memory capability of Illiac. Whatever degree of completeness was achieved would provide an estimate of the size and speed of an optimum control computer. The investigation culminated in the writing and logical testing of an actual control program and the publishing of CSL Report R-74, by Snyder and Fosdick.

Before we proceed to the main business of this paper, the present writer wishes the reader to understand that the original authors do not pretend to be tactical experts, that they make no claim for the logical sufficiency or operational suitability of the control program. The goal they set and successfully attained was "to demonstrate the feasibility and desirability of bringing general purpose computers and general purpose computational methods to bear on the control problem..." It is highly recommended that the reader consult R-74, if not for the detailed description, then at least for the conditional remarks to be found in the introduction and conclusion.

Integration of Control with Surveillance

Cornfield is a laboratory model of an automatic traffic monitoring and control system for use in Naval operations at sea. In the system which it models, a network of radars each with its own raw data processing equipment supplies, via radio link, target position reports to TASC, a central special purpose drum computer which correlates incoming reports to form tracks. This Sorting and Tracking Computer has memory space for 1024 targets on each of which it can store 96 bits of information which include geographical position, drum address, velocities and ancillary data such as track number, gathered from sources other than the radar report net. The ensemble of 96 bits of information on one track is called a word.

In the intervals between incoming radar reports, and on the basis of stored velocities, target positions are brought up to date by smoothed extrapolation every 1.5 seconds.

While accepting, storing and operating on information from radar stations, manual keysets and the automatic control system, TASC also outputs its stored information for distribution on a clear picture network. Seventy-six of the total 96 digits stored on the magnetic drum at each address comprise one complete clear picture word and describe one tracked target. One clear picture word, 76 digits in parallel, is read out from TASC every 20 msec. While there is space for over 1000 targets on the drum, it is expected that under severe conditions only 500 or so of these will represent legitimate, firm tracks to be reported in the clear picture; the rest will be tentative tracks and noise, not firm enough for reporting. Under these conditions, the maximum clear picture frame time will be about 10 seconds.

One of the important users of the clear picture is the control computer which, in the Cornfield experiment, is ILLIAC. It receives the clear picture, word by word, in the form of electrical signals from TASC and, wherever possible, performs all necessary control actions relative to that word or track in the 20 msec before appearance of the next clear picture word.

Action taken by ILLIAC in the processing of any clear picture word may consist in the transmission of a control command to some friendly object, while the nature of the action is indicated by symbols written back into TASC's drum at the address (es) of the object (s) acted upon. Such a feedback link between ILLIAC and TASC completes an information exchange loop between the two computers and decreases the amount of memory space needed in ILLIAC. It also keeps human observers of the clear picture informed of the actions taken by ILLIAC and provides a simple channel for manual overriding or anticipating of any ILLIAC action. A skeleton diagram of the integrated surveillance and control systems is shown in figure 1.

General Description of Control Program

The JNS program, as it will be called in this report, is a set of instructions, formalized for reading into ILLIAC via punched tape, enabling ILLIAC to function as a control computer which performs three kinds of services: threat evaluation, weapon assignment, and the generation of steering instructions for intercept vectoring, direction of strikes, rendezvous, rescue, etc. and return-to-carrier. It can control up to 128 friendly objects against hostile objects whose number is limited only by the sorting and tracking capacity of the surveillance system.

While the controlled objects may be ships, submarines or planes, the program is especially geared to provide fast, frequent, and accurate control information for or against high speed aircraft; slow objects such as ships, which have good facilities for their own control, are dealt with in a much less comprehensive way. This choice was made in order to use the limited abilities of ILLIAC to perform those functions most likely to saturate the abilities of control personnel. Furthermore, a certain amount of arithmetic precision is sacrificed in order to provide more space or time for logical decisions.

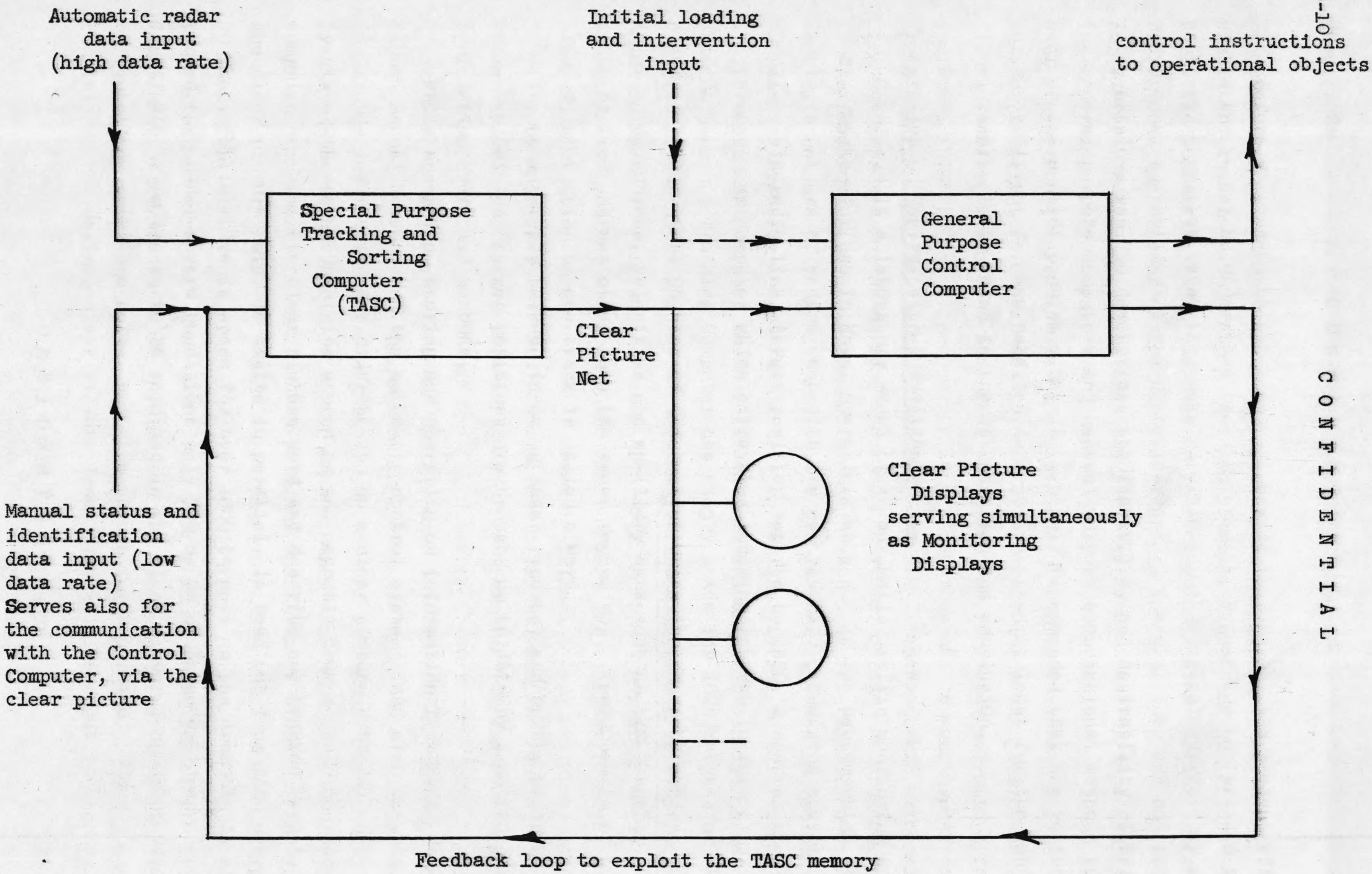

Figure 1 - The Adopted Method of Interconnection between the Surveillance and Control Systems

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Specialized input-output equipment is needed to enable the two computers, TASC and ILLIAC, to talk to each other. The input equipment, ILLI, receives a clear picture word, 76 digits in parallel, from TASC, rearranges the order of the digits and shifts them into ILLIAC tetrad by tetrad. Such handling prepares the word for efficient unpacking and testing by ILLIAC. Subsequent re-reading by ILLIAC of the tetrads of this same word in different ways can be executed and occurs from time to time where necessary. The arrangement of the clear picture word digits as they rest in the ILLI holding register before shifting into ILLIAC is shown in figure 2.

Output messages from ILLIAC are handled by ILLO, a dispatch box which routes the message toward TASC or toward some other discrete address depending on whether the message is a clear picture annotation or a command.

For use in the JNS program, objects tracked by TASC are divided into 16 classes:

Class	Abbreviation	Binary Code
unidentified aircraft	Uac	0000
hostile aircraft	Hac	0100
probable friend aircraft	Pac	1000
friend aircraft	Fac	1100
unidentified ship	Uship	0001
hostile ship	Hship	0101
probable friend ship	Pship	1001
friend ship	Fship	1101
unidentified submarine	Usub	0010
hostile submarine	Hsub	0110
friend submarine	Fsub	1110
Avoidee	Av	0011
Strikee	St	0110
Carrier	Cv	1010
Protectee	Pr	1011
Friendly Other (Ignoree)	Ig	1111

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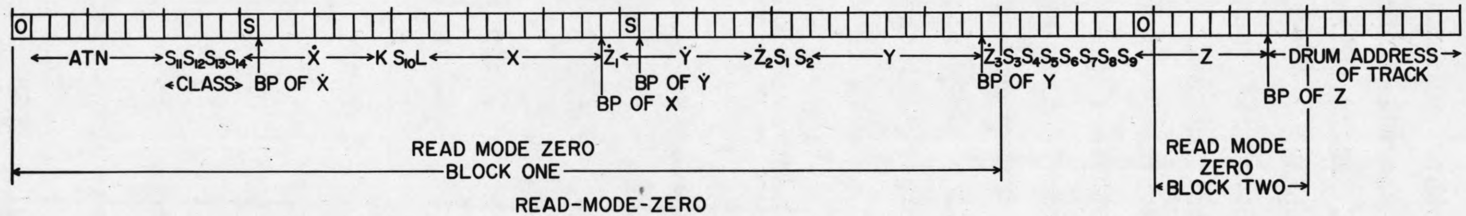

NOTES: THE SPARE DIGIT CAN AND MUST BE SET TO ZERO
BP = BINARY POINT
S = SIGN DIGIT
$S_1, S_2, S_3 --- S_{14}$ = STATUS DIGITS
ATN = ASSIGNED TRACK NUMBER
ONLY 6 OF THE 7 Z DIGITS ARE USED BY THE PROGRAM SO THE FIRST SHOULD BE 0.
THE THREE $\dot{Z}$ DIGITS CAN HAVE ANY VALUE BUT ZERO IS PREFERRED.

FIG. 2 A CLEAR PICTURE WORD IN THE ILLI HOLDING REGISTER

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The third column of the above table shows how four of the 76 binary digits in the clear picture word are employed to encode the classification which serves not only to aid control personnel in identifying tracks as they appear on the displays but also, along with other identity digits, indicates to ILLIAC the nature of processing required for the track.

When a clear picture word is read into ILLIAC the computer determines from the word's class and other identity digits which of the control or evaluation operations are necessary at this time. Those routines of the control program are called into play and the necessary computation, operations, and commands are all made within the 20 msec in which the data expressed by this word are available.

Whenever, due to the nature of the object represented by the clear picture word being processed, it is necessary to record, for use at some future time, information about the action to be taken now, ILLIAC reinserts that information into TASC on that object's track. Each time the object reappears on the clear picture the required information will be present in the word itself and readily available to ILLIAC. Humans monitoring the clear picture may observe this information and thus be informed of the actions of the control computer. For example, whenever a clear picture word representing an unfriendly un-paired object appears, ILLIAC immediately re-evaluates its threat and re-inserts this new valuation into TASC from which it is subsequently displayed on the clear picture. As a further example, whenever a weapon assignment is made by ILLIAC, appropriate marks are inserted into TASC on the tracks of the weapon platform and its target. When displayed on subsequent clear picture frames they reassure human monitors that the assignment has been made and they inform ILLIAC that vectoring or etc. operations and commands should now be generated for the friendly weapon carrier which received the assignment.

It is, of course, not possible to have all pertinent information about a given object present in its clear picture word. The operation to be performed on a given object may require data from some other tracked object; threats are always evaluated with respect to some friendly object; weapon assignments involve both an attacker and a victim; and, further, all steering or vectoring operations involve some object toward which travel instructions are calculated for the traveler. And so it is necessary for ILLIAC to store, in its own fast access memory, information taken from certain clear picture words to be used in the processing of other clear picture words. Finally, there are some data needed by ILLIAC which are not contained in any clear picture word and must, therefore, be stored in ILLIAC before operations begin. Strong attempts have been made in the control program design to hold the amount of information necessary to be thus stored to a minimum.

Some of the consequences of the limited storage available in ILLIAC are:

1. The computer never reviews any of its past actions in order to substitute a better one.
2. Once embarked on a course of action on a tracked object, ILLIAC never terminates this action even when the course of action reaches a natural terminus.
3. In weapon assignment, only a single 1:1 matching of weapon vs. foe can be accomplished.
4. There are a few sequences of operations on a single object which cannot easily be done, even with human assistance.

Limitations 1., 2. and 3. are alleviated or removed by the control personnel. By manipulation of the clear picture word status and identification digits which determine the type of processing to be done by ILLIAC, the operating personnel who are watching clear picture displays can override ILLIAC, make alternate assignments, terminate actions, and designate which, if any, control operations are to be carried out by the computer on particular objects being tracked. This kind of intervention, by manipulation of clear picture digits, is easy to do with engineered keysets, and visual confirmation of manual actions taken comes quickly back to the displays. Intervention into ILLIAC's program, however, is not so easy and, for the most part, is expected to be only infrequently necessary. There are a few conceivable sequences of treatments for a single tracked object which would need human intervention via ILLIAC (rather than via TASC), and it is these that are indicated by limitation 4.

The information on tracked objects which is stored in ILLIAC includes specific characteristics of the 128 friendly objects which can be controlled. It contains such things as the objects' weapon strength, pursuit range, state of readiness, present mission and, for aircraft, the address or name of home carrier. Of the approximately 300 memory locations available in ILLIAC for such storage, 256 of these are used for storing information on the missions of each of the 128 friendly controlled objects. Each of these 128 objects has a unique Assigned Track Number (ATN) which serves not only the control personnel as a name for the track, but also as an address in ILLIAC for locating the pertinent memory bank words. Distribution of ILLIAC memory space as used in the JNS program is shown in figure 3 and summarized in figure 4 taken from R-74.

It can be seen that there are four words in the P-bank. Each word is numbered by an address 1, 2, 3, or 4. The Protectee whose ATN is 3 must be stored at Address 3. In each of these words may be stored the coordinates of one Protectee which must be used by ILLIAC for threat evaluation every time an intruder appears on the clear picture. Next to the P-bank in figure 2 are shown the Carrier banks C_1 and C_2, containing 8 words each. Eight carriers can be accomodated here, with each carrier having one C_1 Bank word and one C_2 bank word. A Carrier whose ATN = 1 and which is also a Protectee would use P-bank No. 1 word, C_1 Bank No. 1 word, and C_2 Bank No. 1 word. It would also use CP Bank No. 1 word to hold the ATN's of its own next 5 carrier planes to be launched. Finally, its mission data would be found in the No. 1 words of the mission banks, B_1 and B_2.

The contents of ILLIAC memory banks are shown in Appendix I for the various classes of controlled objects requiring memory space.

Avoidees, a class which has been briefly referred to but which will be discussed later in this report, require 4 more banks of 6 words each to accomodate 6 Avoidees, one word per Avoidee per bank. A set of 4 words, one from each Avoidee bank, pertaining to a particular Avoidee whose number is $1 \leq i \leq 6$ is shown in Appendix I.

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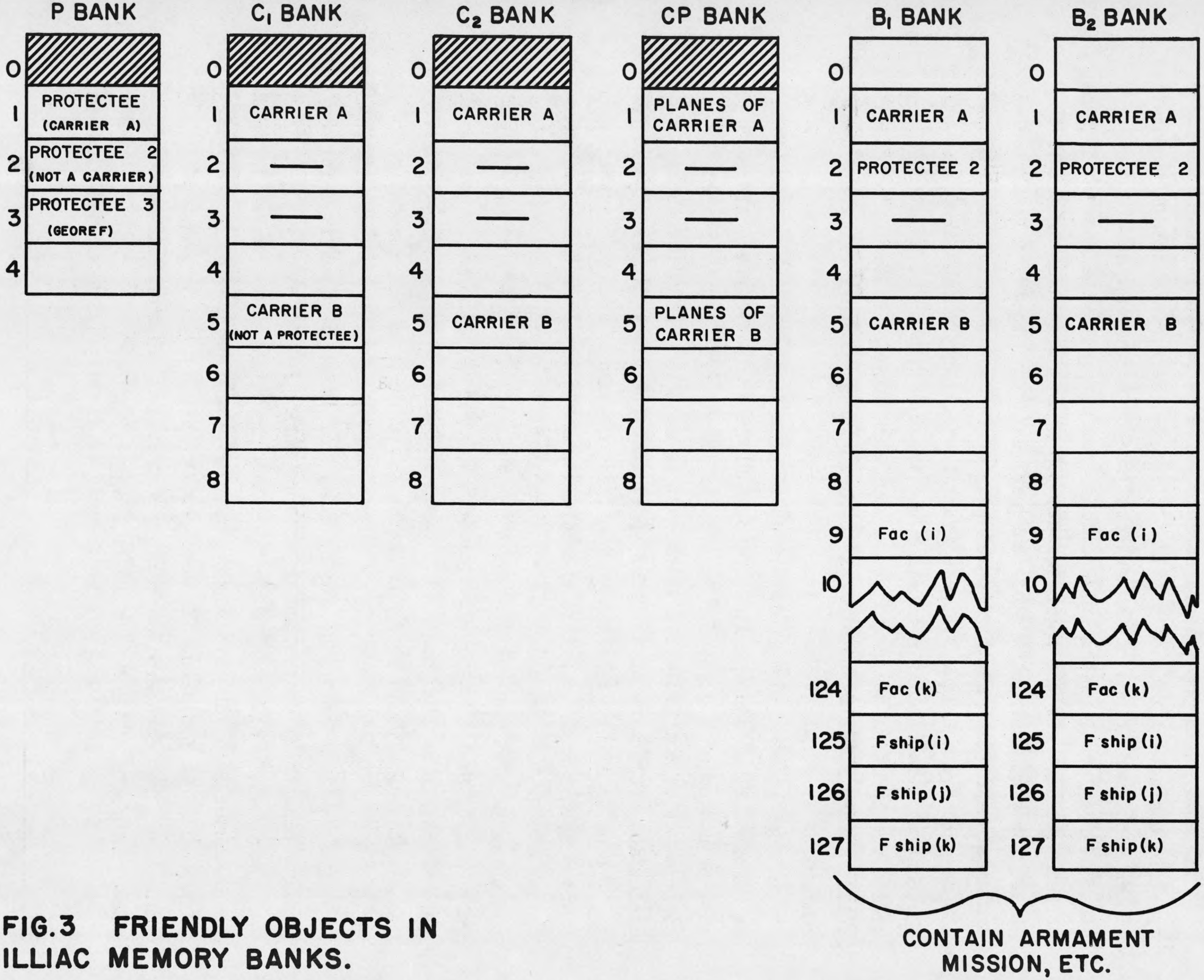

FIG. 3 FRIENDLY OBJECTS IN ILLIAC MEMORY BANKS.

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Type of Operational Object	ILLIAC Storage Banks Used	Permissible Assigned Track Number (ATN) Range	REMARKS
Carrier Not a Protectee	B1, B2, C1, C2, CP	1-8	ATN = 0, permissible but neglected
Protectee Carrier	B1, B2, C1, C2, CP, P	1-4	ATN = 0, permissible but neglected
Georef Protectee	P	1-4	ATN = 0, permissible but neglected
Aircraft Protectee	B1, B2, P	1-4	ATN = 0, permissible but neglected
Surface Protectee	B1, B2, P	1-4	ATN = 0, permissible but neglected
Friend Aircraft	B1, B2	0-127	
Friend Surface	B1, B2	0-127	
Friend Subsurface	B1, B2	0-127	
Friend Other	B1, B2	0-127	If Friend Other is to be processed its ATN must <u>not</u> coincide with that of any other object. If not to be processed, there is <u>no</u> restriction of the ATN.

Figure 4. ILLIAC Memory Storage Banks Used by the Various Types of Friendly Objects

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For completeness, the following rules and limitations apply to assigned track numbers. The friendly object with ATN 0 cannot be assigned to any of the six hostile classes: Unidentified Surface, Unidentified Subsurface, Foe Surface, Foe Subsurface, Probable Friend Surface, or Strikee. The friendly object with ATN 0 can be assigned to the three hostile classes: Unidentified Aircraft, Foe Aircraft, or Probable Friend Aircraft. No Avoidee Number (carried in the ATN digits) interferes with any other ATN in the system. Avoidees with Avoidee Number 0 are not processed. The Frame End Mark Numbers (carried in the ATN digits of especially marked Strikees) do not interfere with any other ATN in the system. It should be recalled that if no weapon is available to assign to a Bogey requiring weapons assignment, a characteristic "warning" broadcast is made to the discrete address receiver corresponding to ATN = 127. Any operational object can actually be assigned ATN = 127; the system will properly carry out all processings and control transmissions to this object. The object will in addition receive the "warning" transmissions. To the extent that this would be confusing, the assignment of ATN = 127 to an actual operational object should be avoided.

Figure 5

Threat Evaluation

In the JNS program, one of the major functions of the control computer is to evaluate the threat posed by aircraft which intrude into the surveillance area. Such aircraft as are classified Unidentified, Hostile, or Probable Friend are considered intruders and are subject to both automatic Threat Evaluation and Weapon Assignment. Objects such as ships or submarines are not so subject, although attack operations can be automatically carried out against them by the computer if a manual assignment is made by the control personnel.

Only friendly objects have Assigned Track Numbers, although the digits of the ATN box on other subclasses of clear picture words have meaning. Until a weapon is assigned to these objects, the content of the ATN box is read as a threat number, T. Initially this number is zero and will gradually be raised by ILLIAC in increments, ΔT, until it passes the weapon threshold for that particular task, whereupon automatic weapon assignment will occur. The method for calculating and applying ΔT is as follows.

A Protectee is a special class of friendly object with respect to which all threats are calculated. It can be chosen from among the ships, carriers, submarines or aircraft of a task group or, if preferred, may be established as a georef point. Two or more Protectees can be designated and deployed to define a particular shape of defense area, although the limit of the present program is four. These four (or less) are chosen by the operating personnel and their identities are loaded into the ILLIAC Protectee memory bank (P-bank) before normal operations begin. During operations, ILLIAC keeps the up-to-date Protectee position coordinates stored in this bank and employs these data for calculating threat increments for non-friendly aircraft, as explained below.

All Protectees, stored in the P-bank possess a pre-set parameter, R_o, which represents the radius of an imaginary circle drawn about each Protectee and is called the "Threat Radius". When an unpaired (no weapon assigned) intruding aircraft appears in a clear picture word, ILLIAC first tests whether T, its threat index, has yet exceeded the threshold for weapons assignment. If not, it immediately calculates the range to each Protectee, rejecting all but the least.

Having found the nearest Protectee, ILLIAC proceeds to calculate an increment which it will add to the threat index of the bogey. (For brevity the intruding aircraft will be called a "bogey" in this discussion although he may actually be an identified Hostile or a Probable Friend.) In this calculation, three criteria, size, range, and closing velocity are used which are incorporated as terms of the equation

$$\Delta T = (\Delta T)_s + (\Delta T)_R + (\Delta T)_v.$$

$(\Delta T)_s$ is the threat increment due to size or importance. It is zero if the clear picture size digit, S_2, is zero. If $S_2 = 1$, ILLIAC inserts that fixed value of $(\Delta T)_s$ which the control personnel have originally installed in ILLIAC's control parameter storage bank. $(\Delta T)_R$ is the threat increment due to penetration of the threat radius, and is numerically equal to C_R $(R_o - R)$ where C_R is a pre-set weighting parameter, R_o the pre-set Threat Radius of the Protectee, and R is the "10 °/o Range"* to the Protectee.

$(\Delta T)_v$ is the threat increment due to the bogey's closing velocity on the Protectee and is equal to $C_v \cdot \frac{\vec{V} \cdot \vec{R}}{|R|}$, where C_v is a pre-set weighting constant and $\vec{V}$ is the bogey's velocity. If ΔX and ΔY are the components of range $\vec{R}$ from the bogey to the Protectee and $\dot{x}$ and $\dot{y}$ the bogey's velocity components, then ILLIAC evaluates $\frac{\vec{V} \cdot \vec{R}}{|R|}$ as

$$\frac{\vec{V} \cdot \vec{R}}{|R|} = \frac{\dot{x}(\Delta x) + \dot{y}\,(\Delta y)}{R}$$

which is equivalent to $V \cos \theta_{(V,R)}$.

Having assembled ΔT according to the rules just explained, this increment is added to the old threat number, T, and the resulting new threat number is written back into TASC at the bogey's address.

Attention is called to the fact that the terms(s) $(\Delta T)_R$ and/or

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* All distances calculated for threat evaluation are done by means of a simple approximation. The distance, R, between two points whose rectangular components of separation are ΔX and ΔY is given by $R \simeq |L| + \frac{|S|}{2}$ where $|L|$ is the larger of $|\Delta X|$ or $|\Delta Y|$ and $|S|$ is the smaller. The error in this calculation is always positive and varies from zero, when either ΔX or ΔY is zero, to a maximum of 11.8 °/o, when one component is twice as large as the other. Hereafter in this report we shall refer to any range approximated by this method as "10 °/o R".

$(\Delta T)_V$ may sometimes be negative depending respectively on whether the bogey is outside the threat radius R_o and/or whether it is moving away from, rather than toward, the Protectee. Thus the total increment $\Delta T = (\Delta T)_S + (\Delta T)_R + (\Delta T)_V$ may be negative, and the new threat number may sometimes be smaller than the old. A bogey could fly into the fringes of the surveillance area and, without exceeding threat threshold for weapon assignment, fly out again without being attacked. During this maneuver, a clear picture observer would see the threat index at first increase and then decrease back to zero.

A thumbnail sketch of the operational details of Threat Evaluation is presented below for reference by control personnel.

(i) $\Delta T = (\Delta T)_S + (\Delta T)_R + (\Delta T)_V$

$$= (\Delta T)_S + \underbrace{C_R(R_o - R)}_{\substack{\text{Threat increment}\\ \text{per mile}\\ \text{penetration}}} + \underbrace{C_V \frac{\vec{V}.\vec{R}}{|R|}}_{\substack{\text{Threat increment}\\ \text{per 1.5 secs of}\\ \text{closing velocity}}}$$

$$\frac{\vec{V}.\vec{R}}{|R|} = \frac{\dot{x}(\Delta x) + \dot{y}(\Delta y)}{R}$$

$(\Delta T)_S \leqq 2^{20} + 2^{19} + 2^{18} \ldots\ldots\ldots\ldots 2^1 + 2^0.$

$R_o \leqq 511$ miles

$C_R \leqq 2^{21} + 2^{20} + 2^{19} \ldots\ldots\ldots\ldots 2^1 + 2^0$. plus fractions.

$V = \sqrt{\dot{x}^2 + \dot{y}^2}$

$$\dot{x} \leqq (\mp)\ 2^{-1} + 2^{-2} + 2^{-3} + 2^{-4} + 2^{-5} + 2^{-6}\ \frac{\text{miles}}{1.5\text{ secs}}$$

$$\leqq (\mp)\ 1/2 + 1/4 + 1/8 + 1/16 + 1/32 + 1/64\ \frac{\text{miles}}{1.5\text{ secs}}$$

$$\leqq 2400 \text{ knots}$$

So $V \leqq 3600$ knots

$C_V \leqq 2^{39} + 2^{38} + 2^{37} \ldots\ldots\ldots\ldots 2^1 + 2^0$

(ii) 10 °/o R is used for finding R and closest Protectee

(iii) T never goes below zero (although sometimes $\Delta T < 0$)

(iv) Threat Thresholds T_{0000th}, T_{0100th}, and T_{1000th} should be chosen substantially less than 127, preferably less than 120, so that T cannot recycle. If threat threshold were 125 and $\Delta T = 2$, T would pass the Weapon Assignment threshold without being detected, and return to zero. (see Weapon Assignment for significance of threat thresholds.)

Weapon Assignment

Threat Evaluation, per se, in the JNS Program makes no distinction between the three non-Friendly subclasses of aircraft*; it is only at the transition from Threat Evaluation to Weapon Assignment that the distinction is made. Each of these three classes is given an independent threat index threshold for Weapon Assignment which is selected and inserted by control personnel into ILLIAC's control parameter memory bank. Whenever an unpaired (unassigned) UHP aircraft appears on the clear picture wires, the control computer, before calculating a new ΔT, first tests whether the threat number, T, has yet exceeded $T_{threshold}$ for that class.

Here and in R-74 the notations T_{0000th}, T_{0100th}, and T_{1000th} are used to designate the Threat Number thresholds for Unidentified, Hostile, and Probable Friend aircraft, respectively. By a suitable choice of relative values for the $T_{thresh.}$'s, one may set the relative tolerance of the automatic defense system for the three classes of intruders. Thus, generally speaking, one might expect to provide a significantly lower threshold, T_{0100th}, for a Hostile than for a Probable Friend, thereby allowing more time for a proper identification of the latter before pairing him with a weapon. On the other hand, existing doctrine may dictate that the only safe distinctions allowable are between UHPac and Fac, that all UHPac should be treated alike by setting $T_{0000th} = T_{0100th} = T_{1000th}$. Such choices are provided for the control personnel within the flexibility

* Throughout this report reference is frequently made to the three non-Friendly subclasses: Unidentified, Hostile, Probable Friend. For convenience here, and on some of the actual control equipment, the abbreviation UHP is employed. Thus UHPac means Unidentified, Hostile or Probable Friend aircraft. Similar abbreviations are used for other objects such as F-ship (Friend Ship,) UHF-sub (Unidentified, Hostile, or Friend Submarine, etc.)

of the control parameters.

If, on testing whether T has exceeded $T_{thresh.}$, ILLIAC finds that such is the case, threat evaluation stops and control is immediately transferred to the Weapons Assigner portion of the program, if it is not already in use. By it, the pertinent data relative to the bogey are written into a set of temporary storage registers called the Bogey Bank, and the bogey's speed $|\vec{V}_B|$ is calculated (10 °/o) and recorded. Storing of bogey in the Bogey Bank is tantamount to setting a "Weapons Assigner On" switch to positive and insures that no other weapon assignment can be initiated before the current one is completed.

Completion of a Weapon Assignment takes slightly more than one clear picture frame time. In this interval every available weapon will appear to ILLIAC, one by one in the clear picture transmission and, because the Weapon Assigner is "on", will be tested for possible assignment to the bogey. Preliminary tests are carried out on each friendly weapon as it appears on the clear picture to ascertain if an assignment is even reasonable. If these tests are passed, then a calculated suitability index R_c of that weapon is compared with the recorded R_c of the best weapon of that type so far encountered in the frame. If the new weapon under test is found to be more suitable, then its identity and capability is substituted for the one previously temporarily stored and is used for comparison against any additional weapons of its type which may appear in the frame. As a consequence of these actions, at the end of the weapon assignment frame ILLIAC has in temporary storage the best of <u>each</u> type of friendly weapon available for the assignment.

The JNS Program recognizes four types of weapons for use against aircraft: AA guns (or short range missiles), aircraft on combat patrol, carrier planes ready for launching, and long range AA missiles*. During a weapon assignment frame each of these types is evaluated independently until the frame ends. Thus, when the frame is finished, the temporary storage locations provided for the purpose will contain information on the identity and capability of

1. the best gun

and 2. the best CAP plane (airborne)

* For concreteness we have chosen TALOS as the particular long range missile.

and 3. the best carrier plane (on deck)

and 4. the best TALOS (launcher).

At this time, 40 msecs. is provided for the Overall Weapon Assigner portion of the program to choose one from among these four weapons and actually make the assignment by

(a) sending an announcement message to the (Friendly) weapon or its platform,

(b) making appropriate changes in the clear picture word of the Friendly to indicate the mission,

(c) making appropriate changes in the clear picture word of the bogey to indicate the kind of defensive reaction in progress. In the event of a plane or gun assignment the bogey threat number will be overwritten by the ATN of the assigned Friendly; S_1 will be set = 1 to indicate this new meaning of the T-ATN box numbers; and S_3 will be either set = 1 or left = 0 depending on whether a Friendly gun or Friendly plane received the assignment. In the event of a missile assignment, the bogey's class will be changed to Avoidee and other operations will be performed which we shall discuss later.

Thereafter, whenever the bogey appears on the clear picture, ILLIAC will know from the fact that S_1 = 1 that it has in hand a paired bogey whose up-to-date position and velocity it must extract and save for transmission to its paired Friendly. The required data is extracted from the Bogey's clear picture word and stored in the two ILLIAC mission bank words of the appropriate Friendly, the address of the latter being obtained from the ATN which appears on the bogey's clear picture word. Whenever the Friendly re-appears on the clear picture, ILLIAC will furnish steering or aiming advice regarding its paired bogey. In order to promptly accomplish this, ILLIAC need only consult the Friend's mission bank words where the bogey information is stored, perform the simple calculations, and output a message via the discrete address communication link.

Some of the details of how the 1-frame Weapon Assignment search is carried out will be given below and will include the nature of the tests conducted on clear picture words representing potential weapons for assignment.

Frame Marks

Having stored a bogey in the Bogey Bank, ILLIAC is faced with the need for listening to the clear picture for exactly one frame to find a weapon. At the end of the frame certain operations must be carried out which could take more than the 20 msecs. duration of a clear picture word. To assist in these requirements, two artificial permanent tracks are kept on the clear picture for use as FRAME END MARKS and are called FEM-0 and FEM-1. Their class digits S_{11} - S_{14} are marked 0111, Strikee, but these objects are distinguished from valid Strikees by their S_1 digit which is always set to 1. Valid Strikees (which are always mission targets of some kind) are recognized by $S_1 = 0$.

It was felt that, besides the two marks required by the control program, additional fictitious marking tracks might be useful for other purposes on the clear picture. A total of 4 could be used to mark the corners of the 511 x 511 mile surveillance area. Any number needed may be added (up to a ridiculous 125) but ATN = 0 and ATN = 1 are reserved for the two required marks, FEM-0 and FEM-1, respectively. Fictitious tracks labeled STRIKEE, $S_1 = 1$, ATN $\geqq$ 2 will not interfere with the action of FEM-0 or FEM-1 in Weapon Assignment, nor with the action taken on valid STRIKEES ($S_1 = 0$) which may bear the same ATN.

When ILLIAC finds a Bogey over threat threshold, stores him in the Bogey Bank, and turns "on" the Weapon Assigner portion of the program, it continues processing subsequent clear picture words in the normal fashion until it encounters a FRAME END MARK. When this occurs, ILLIAC begins the weapon search. As each successive clear picture word comes in, ILLIAC tests its class. If it is a UHP a/c which is already paired with (assigned to) a weapon, the coordinates and velocity are extracted and saved for subsequent broadcast to the paired Friend. If it is a UHP a/c which has not yet passed threat threshold, a new threat number is calculated and written back into TASC. These are normal actions which occur whether or not Weapons Assigner is "on". If, on the other hand, a UHP object appears which needs Weapon Assignment, this action is deferred. At some later appearance on the clear picture cycle this need will still be apparent and the Weapon Assigner may not be already occupied and can be engaged. Finally, if any Friendly object appears to ILLIAC during the Weapon Assignment search frame, a series of tests, depending on its specific class, are applied to measure the Friend's suitability for assignment to the waiting bogey.

These tests are described at length in R-74 but are distributed throughout that report, appearing in descriptions of the complete treatment for given classes and separated under class headings. They appear in the present paper all in one section but in considerably reduced form, without much of the interesting discussion which the reader may find in R-74.

Weapons Assignment Tests

It should be recalled that the identity and certain characteristics of up to 128 friendly objects are stored in ILLIAC's memory banks. These data supplement the small amount of information in the clear picture word. Whenever a clear picture word corresponding to one of the friendly objects enters ILLIAC on the clear picture cycle, the (weapon) memory banks may be consulted, the proper address being obtained or generated from the ATN found in the clear picture word itself. Any friendly objects which are armed may be considered for assignment to destroy a bogey*.

In addition to specific characteristics of individually identified friendly objects which are stored in the weapon banks (called "Mission Banks"), certain other group characteristics of weapon types are stored as pre-set parameters in the Control Parameter bank. They include such things as

i Maximum initial range for gun weapon assignment

ii Maximum altitude for gun weapon assignment

iii Maximum and minimum ranges for carrier plane mission

iv Maximum and minimum missile ranges. (TALOS)

and others which are used in the search for an available suitable weapon and are involved in the following tests.

Weapon Assignment Tests for GUN

During a Weapon Assignment clear picture frame, any objects of the

* The word bogey is used in this report as in R-74 only to avoid tiresome repetition of the word UHPac (≡ UPH a/c). While its strict meaning is "Unidentified aircraft", the reader may safely substitute Unident., Hostile, or Prob. Friend a/c, whenever "Bogey" is encountered.

classes, CARRIER (1010), PROTECTEE (1011) (but only if $S_2 = 1$, "Surface") or FRIEND SURFACE (1101), all of which are AA gun platforms, are subjected to certain tests to determine the feasibility of assigning the bogey to one of them. This is done in lieu of the vectoring which would occur if the Weapon Assigner were not "on".

(a) The bogey's altitude Z_B is tested to make sure it does not exceed the maximum vertical gun range Z_G.

(b) The slant range to bogey's present position $R_{FS \rightarrow B}$ must not exceed the maximum gun assignment range R_{GM}.

(c) The bogey must be closing on the gun platform in question:

$$\left[-\vec{V}_B \cdot \vec{R}_{B \rightarrow FS} < 1 \right]$$

(d) The distance of predicted closest approach is calculated to see if the bogey will subsequently come within gun range:

$$\frac{\left| \vec{V}_E \times \vec{R}_{B \rightarrow FS} \right|}{\left| \vec{V}_B \right|} < R_G$$

During the weapon assignment search, several possible AA gun candidates may be found and a means for designating the "best" of these is provided. If tests abcd are passed, the surface vessel under test represents a possible choice for the assignment. Its present range to the bogey, $R_{FS \rightarrow B}$, is used as a criterion and is called the "Characteristic distance for gun, R_{CG}". The smallest R_{CG} of any ship so far encountered is temporarily stored, along with the ship's identity, in a special memory bank called "best gun". Whenever, during the frame, a vessel with a smaller R_{CG} is found, this new ship will replace the one previously stored under "best gun". Hence, at the end of the search frame, the memory location "best gun" will contain the R_{CG} and identity of the nearest AA platform capable of taking the assignment.

Weapons Assignment Tests for CAP

Aircraft on combat patrol are recognized by ILLIAC from their clear picture word class digits $S_{11}\ S_{12}\ S_{13}\ S_{14}$ (1100 $\Leftrightarrow$ FRIENDLY A/C) and their mission digits $S_1 S_2$ (00 $\Leftrightarrow$ CAP). When one of these is encountered in a weapon assignment search, it must first be ascertained whether enough fuel remains to safely make the intercept and return. The ability to make this decision depends upon the maintenance of an up-to-date posting of the fuel remaining in each patrol plane aloft. Digits $S_3S_4S_5S_6$ of the clear picture word are provided to carry this notation and it is the responsibility of the control personnel to manually insert this datum via keyset on advice from the aircraft pilots. More sophisticated techniques such as fuel dead reckoning or telemetering are possible but have not been employed for this elementary program.

In calculating fuel-needed (G_{NEEDED}) for comparison with fuel-has (G_{HAS}) a simplification and a safety factor are introduced by assuming that the distance to be flown is a round trip to the present position of the bogey. But since no intercepts are ever assigned on a bogey which is not closing the CAP, the round trip to the actual intercept point will probably be less unless highly evasive maneuvers are encountered. Hence, ILLIAC first calculates $R_{P \rightarrow B}$, the 10 °/o range from the CAP in question to the bogey, and subsequently calculates $g(R_{P \rightarrow B}) = G_{NEEDED}$. The fuel comsumption parameter, g = fuel per round trip mile, is one of the pieces of information stored by ILLIAC on each friendly aircraft under its control.

If the CAP passes the first test, $g(R_{P \rightarrow B}) = G_{NEEDED} = G_{HAS}$, a second test is imposed to discover if the bogey is closing on the CAP, the test being $-\vec{V}_B \cdot \vec{R}_{P \rightarrow B} < 1$. Upon passing this test, the characteristic distance $R_{CP} = R_{P \rightarrow B}$ is compared with the "best" one so far encountered. The plane with the smaller R_{CP} is temporarily stored in memory location "Best CAP".

Weapon Assignment for Carrier Plane (on deck)

In those paragraphs above which describe Weapon Assignment tests for GUN, it was said that all armed surface vessels are tested for a possible gun assignment. This of course includes CARRIERS. However, a CARRIER may possess a more effective and desirable weapon in the form of a combat plane ready for launching and so must undergo further tests to discover if this is so.

Like any other weapon, a deck plane has a maximum range, beyond which it cannot carry out intercept missions. Unlike airborne CAP planes, a deck plane requires significant time for launching and achieving altitude and should not be assigned to intercepts which are close-in. Two control parameters, R_{CPM} and R_{CPm}, which define the maximum and minimum assignment ranges are stored in the ILLIAC Control Parameter Bank and are used to test whether the distance $R_{FS \to B}$ from Friend Surface (here Carrier) to Bogey falls within practical limits.

If the range tests are passed, and although further tests are necessary before it is certain that an intercept by one of its planes is even possible, ILLIAC at this moment tests to see if the present CARRIER would be a better assignment than the last one tentatively stored (as a deck plane) under "best CARRIER PLANE". If the CARRIER in hand represents no improvement, there will be enough time remaining from the original 20 msec. to enter the FRIEND SURFACE routines and either carry out a gun weapon assignment or a vectoring operation.

The measure of worth for the assignment is taken to be $R_{CCP} = R_{FS \to B}$. The CARRIER closer to the bogey, i.e. with smaller R_{CCP}, is regarded as the better assignment. If the CARRIER at hand meets this criterion, further tests for practicality are carried out.

The first of these is to learn whether the CARRIER has planes available. This test is accomplished by examining the CP-Bank word whose address corresponds to the CARRIER under test. Each CARRIER recorded in ILLIAC's memory banks has one CP-Bank word which (if full) contains the ATN's of the next five interceptors ready for launching. As they are used up (by receiving assignments) ILLIAC will shift them out of the left hand end of the register and the register may become exhausted (all zeros). It is the duty of the control personnel to keep these memory spaces supplied with ATN's as long as there are corresponding planes in readiness.

Should ILLIAC find there is at least one plane in readiness aboard the CARRIER it finally computes the scalar quantity $-\vec{V}_V \cdot \vec{R}_{B \to FS}$ to see if the bogey is closing the CARRIER. If the result is negative, the bogey is indeed closing, and the CARRIER ATN, the CARRIER PLANE ATN and the characteristic distance, R_{CCP}, are all stored in the "Best CARRIER PLANE" location for later use by the overall weapons assignment routines.

Weapon Assignment Tests for TALOS

TALOS weapon assignment tests are, like those for (AA) guns, part of the FRIEND SURFACE routines. Either TALOS tests or "gun" tests are conducted on each FRIEND SURFACE during a weapon search frame. Ships are regarded either as Talos platforms or as (AA) "gun" platforms, but not both. They are distinguished in ILLIAC by two armament type digits found in the Bank 1 word and which must be pre-set by control personnel. 00 $\rightleftharpoons$ unarmed, 01 $\rightleftharpoons$ guns, 10 or 11 $\rightleftharpoons$ Talos.

Like CARRIER PLANES, missiles such as Talos require targets which lie in a ring shaped area centered around the launcher. The outer radius (R_{TM}) of the ring is closely related to the maximum flight range of the weapon while the inner radius (R_{Tm}) is a function of acquisition and launching time, and time for firm control to be established by the guidance radar.

In testing a TALOS ship for possible assignment, if ILLIAC decides that the ship's range-to-the-bogey, $R_{FS \rightarrow B}$, lies between the maximum and minimum TALOS assignment ranges, R_{TM} and R_{Tm}, the assignment is regarded as a possible one. It remains to be compared with other possible TALOS (launcher) assignments that may be found in the same weapon search frame and, for this purpose, the quantity $R_{CT} = R_{TM} - R_{FS \rightarrow B}$ is calculated and compared with the one currently held in the "Best Talos" memory location. Since the quantity R_{CT} for a Talos ship is considered "better" whenever it is smaller, the test has the property of choosing that TALOS ship which is farther from the target, providing more time for target location, launching, and lock-on.

Thumbnail Sketch of Weapon Assignment Tests

Gun: $Z_B < Z_G$

$R_{FS \rightarrow B} < R_{GM}$

$-\vec{V}_B \cdot \vec{R}_{B \rightarrow FS} < 1$ (closing)

$$\frac{\left|\vec{V}_B \times \vec{R}_{B \rightarrow FS}\right|}{\left|\vec{V}_B\right|} < R_G$$

$R_{CG} = R_{FS \rightarrow B}$

CAP: calc. 10 $^{o}/_{o}$ $R_{P \to B}$, $gR_{P \to B} = G_{Needed}$

test $G_{Needed} \leq G_{HAS}$ $(S_3 - S_6)$

$-\vec{V}_B \cdot \vec{R}_{B \to F} < 1$ (closing)

$R_{CP} = R_{P \to B}$

CARRIER PLANE: $R_{F \to B} < R_{CP_{Max}}$ and $R_{F \to B} > R_{CP_{Min}}$

Has planes? Ready to launch?

$-\vec{V}_B \cdot \vec{R}_{B \to F} < 1$ (closing)

$R_{CCP} = R_{F \to B}$

TALOS: $R_{T_{Min}} < R_{FS \to B} < R_{T_{Max}}$

$R_{CT} = R_{T_{Max}} - R_{FS \to B}$

Launch point closest to max. range is "best."

Overall Weapon Assignment

The pages immediately above have described how ILLIAC searches through one frame of clear picture words, determining which CAP planes, Carrier (deck) planes, AA "guns", and TALOS ships are capable of taking an assignment to the bogey which is temporarily stored in the bogey bank awaiting assignment. In carrying out the search, ILLIAC has saved in four special storage locations the identity of the best weapon of each type. Throughout the frame, as it came across better weapons it changed the contents of these four storage words to correspond to its latest findings. Finally, at the end of the weapon search frame, ILLIAC has stored

1. Best CAP (ATN, DA, R_{cp})
2. Best CARRIER A/C (ATN_{plane}, $ATN_{carrier}$, R_{cc})
3. Best TALOS ship (ATN, R_{ct})
4. Best GUN (AA ship) (ATN, DA, R_{cg})

The R_c's are called Characteristic Distances and may be used as criteria of merit within each weapon class. However, since the characteristic distances are not all defined alike, and the effectiveness of the weapons differ for one reason or another, the R_c's for the four "best" weapons cannot be directly compared. To make them comparable and to provide a basis for selection of the one "best" from among the four "best" weapons, special weighting factors α_i are applied to the R_c's to yield figures of merit, $(FM)_i$.

1. $(FM)_p = \alpha_p R_{cp}$
2. $(FM)_c = \alpha_c R_{cc}$
3. $(FM)_t = \alpha_t R_{ct}$
4. $(FM)_g = \alpha_g R_{cg}$

Each of the control parameters α_i may be set independently by the control personnel and can be chosen in such a way as to establish selection priorities among the four weapon types.

If it is desired, the priority may be made absolute so that, regardless of range, a certain weapon type, if available, will always be chosen over any other. For example, it may be arranged that, when available, a CAP will always be assigned before a carrier plane, a carrier plane before a TALOS, a TALOS before a gun. A more sophisticated choice preferred by the author is described in Appendix II where, for the benefit of control personnel, the weapon assignment priority problem is discussed more fully.

Having constructed the $(FM)_i$'s and inserted them in the four "Best Weapon" memory words, the computer now has all the information it needs to actually make the weapon assignment. Comparing the $(FM)_i$'s, it chooses the weapon with the smallest (FM) and executes the proper write outputs.

1. If the bogey is assigned to a friendly plane on combat air patrol, ILLIAC

   a. writes the friend's ATN into the bogey's threat number-ATN box on the bogey's memory word in TASC,

   b. changes the bogey's S_1 (in TASC) to 1 to indicate it as now assigned,

   c. changes the friend's S_1S_2 (in TASC) to 01 to indicate it as on an intercept mission, and d. broadcasts a type 1(B) message to friend's discrete address receiver to indicate change of mission from CAP to INTERCEPT.

On each appearance of the bogey on subsequent clear picture frames, the bogey's position and velocity coordinates will be extracted and written into the friend's mission bank in ILLIAC, the proper address being found from the friend's ATN which was written into the bogey's clear picture word threat number box at the time of weapon assignment.

On subsequent clear picture appearances of the friend now on intercept, the up-to-date bogey coordinates found in the friend's mission bank words are employed in the computation of a mission vector.

2. If the bogey is assigned to a carrier (plane, on deck) ILLIAC
   a. Writes the carrier plane's ATN into the bogey's threat number-ATN box in TASC,
   b. changes the bogey's $S_1 \rightarrow 1$ to indicate "assigned",
   c. changes the friendly plane's $S_1 S_2 \rightarrow 01$ to indicate INTERCEPT MISSION,

   and d. broadcasts a type 1(B) message to the friendly plane (this would normally be received by the carrier) to alert it for the intercept mission.

Vectors for the mission are computed from information obtained and recorded in the same way as for intercept assignments which fall to CAP.

3. If the bogey is assigned to Talos, ILLIAC
   a. changes the bogey's class from Unidentified a/c to Avoidee,
   b. writes a preliminary Avoidee number of 64 into the bogey's threat number-ATN box,
   c. Sets bogey's (now Avoidee) $S_1 \rightarrow 1$, indicating PRIORITY Avoidee,
   d. writes the standard TALOS avoidance area dimensions, Δx and Δy, into S_4 - S_9,
   e. outputs a type 1(B) message to the friendly (Talos) ship, alerting it to its assignment and giving bogey's coordinates and drum address.

On the next appearance of the "bogey", now an Avoidee, ILLIAC detects from its number, 64, that it is a new Talos target, therefore a new priority Avoidee requiring storage in ILLIAC's Avoidee bank. During vectoring routines for friendly aircraft, ILLIAC always checks these banks to see whether the aircraft is in any of the Avoidee areas, and if so, modifies its vectoring accordingly. Bookkeeping rules for Avoidees are discussed later under "Object Class Characteristics--Avoidees".

4. If the bogey is assigned to "GUNS", Illiac
   a. writes the friendly "gun" platform's ATN into the bogey's ATN box,
   b. changes the bogey's S_1 digit $\rightarrow 1$, indicating "assigned",
   c. changes the bogey's $S_3 \rightarrow 1$, indicating "to 'guns'",
   d. outputs a type 1(B) message to the "gun" platform, giving bogey's spatial coordinates and drum address. Quotation marks around the word, GUNS, are provided because this author wishes to indicate that this category need not be considered specific. Because of their elementary nature, the "gun" routines of this program are equally applicable to (though not necessarily sufficient for) all short range missiles, ballistic (shells, etc.) or otherwise (rockets, etc.).

5. If there is no weapon at all available, the overall weapons assignment routine will find the "Best Weapon" storage banks empty, and a warning will be transmitted. This always has the form of a GUN weapon assignment message to the special address, ATN = 127 (decimal, 7L sexadecimal).

Vectoring

Vectoring can be provided for all classes of friendly objects but, for the sake of economy, a distinction is made between the type of guidance calculated for aircraft and the type provided for the slow moving surface vessels. In bringing two friendly ships together, it scarcely matters whether one is directed on a collision course or a pursuit course if the vectored ship has a noticeable speed advantage, and that can be arranged at leisure. Furthermore, any navigator who is steadily receiving pursuit course vectors (range and bearing, present position) to another ship can very easily employ them in re-calculating an exact or approximate collision course. On the other hand, it is highly desirable that an airborne interceptor be guided on a pre-calculated collision course in such a way as to allow the final approach to be made from some optimum angle.

When the original program was written, recommended directions for final approach were between 15° ahead of, and 30° behind, the line through the bogey perpendicular to the bogey's heading; acceptable angles were from 60° ahead to 60° behind. These or any other arbitrary final approaches could be guaranteed for most intercepts if only the program had the capacity to calculate an initial off-set. Since minimum initial offset cannot be guaranteed, the original program suffers from a very serious fault not foreseen when it was first designed. The important control parameter $\underline{\alpha}$ is subject to severe restrictions in value. If the ratio of $\frac{1/\alpha}{v_{Bogey}}$ is too small, interceptions will be terminated at any time the bogey flies directly toward the interceptor, regardless of range, and will be terminated at various ranges if only most of the bogey's velocity is toward the interceptor.

To understand this limitation it is necessary to first understand the original program, a description of which follows immediately below. After that, the reader will find a detailed discussion of the limitation and a proposal for how to live with it.

JNS A/C Vectoring Routines

An economical concession to simplicity is the calculation of a pseudo-collision course instead of a true one. Like the true point of collision, the pseudo-collision point defined by Snyder's approximation lies on the projection of the bogey's flight. Generally it lies further ahead and, as the range draws nearer, the pseudo-collision point moves continuously inward, along the bogey's projected flight path, always approaching the true collision point. At a cost of flying intercepts on a slightly longer path significant savings in the arithmetic and programming are accomplished by the simplification.

Figure 6 illustrates some of the quantities employed in calculating the pseudo-collision point.

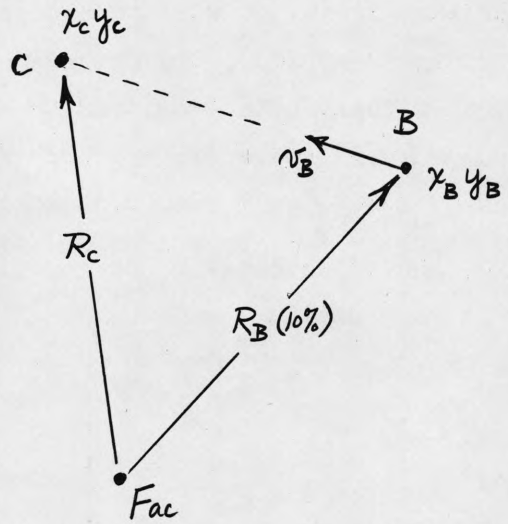
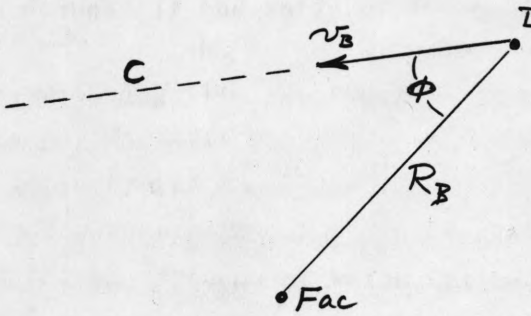


Fig. 6

Point B represents the position $x_B y_B$ of a bogey whose course is directed along the line BC with velocity $\vec{v}_B$. Fac represents a friendly interceptor (whose velocity $\vec{v}_F$ is not shown). Point C is the point on the bogey's projected track where collision would occur if the friend were vectored at speed v_F on a straight collision course. The problem is to find the coordinates x_c, y_c of point C in order to calculate the intercept vector R_c.

Plainly, the distance BC is just $v_B t^*$ where t^* is the time to intercept, and the x-coordinate of the collision point is $x_c = x_B + \dot{x}_B t^*$. But the exact expression for t^* is complex and would require a relatively long time to calculate. The Snyder economy is to approximate t^* by calling it the time required for the Fac to fly the distance R_B to the bogey if the bogey were at rest. Thus, instead of calculating $t^* = \frac{1}{v_F} R_c$ which is impossible since R_c is the principal unknown, the program calculates $t^* = t' = \frac{1}{v_F} R_B$, where R_B is the 10 °/o approximation of the present distance to the bogey. A final economy is invoked in taking the speed of the friend, v_F, to be a pre-set constant, $\frac{1}{\alpha}$. The resulting expression for x_c is now $x_c = x_B + \dot{x}_B \alpha R_B$ and y_c is $y_c = y_B + \dot{y} \alpha R_B$.

At first hand it may not be obvious that the substitution of a fixed constant, α, for $\frac{1}{v_F}$ is economical or advantageous, particularly when v_F is easily available to ILLIAC. To appreciate some of its usefullness, it is necessary to consider the effect of α larger or smaller than the exact v_F. Without recourse to the mathematical treatment contributed by P. G. Braunfeld in R-74, it is intuitively apparent that if we employ an α which assumes a greater speed for the interceptor than it actually has (i.e. $\alpha < \frac{1}{v_F}$), the friendly aircraft will not quantitatively fulfill ILLIAC's trusting expectation. Every few seconds, when ILLIAC calculates a new vector, "thinking" that the interceptor it is guiding is actually faster than it is, it will tend to provide an insufficient lead. As the interception draws to a close, the error in lead angle approaches zero, but the interceptor has already been committed to a later interception than was first calculated and will therefore approach from a more sternward direction. Extreme choices of $\alpha \ll \frac{1}{v_F}$ will result in tail chases for all cases except those in which $\emptyset$, the angle between the bogey's course and the friend's starting position, is very small.



Similarly, when $\alpha \gg \frac{1}{v_F}$, ILLIAC assumes the friend is much slower than he really is, calculates excessively large leads, and tends to bring about a head-on interception.

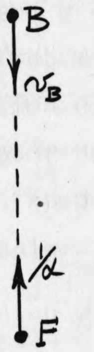
Thus, for any one value of ϕ and of v_F it is possible to choose an α which will tailor the angle of final approach to any desired value. A standard operational agreement based on the particular types of interceptors carried in a Task Group may fix v_F, but ϕ is difficult to control. Consequently, the pre-set parameter, α, when used in the present control program, is optimized for a particular v_F over a wide class of ϕ's.

In a slightly more sophisticated program, the Weapon Assigner could be instructed to reject all tentative intercept assignments for which ϕ was not suitable. With additional increases in computing capacity, several more refinements would be expected, not the least of which would be an intelligent method for overcoming altitude disadvantages by flying a curved interception path. For the present, since the interception path is not programmed in any way to gain altitude, the Weapons Assigner is forced to employ minimum assignment ranges which are generously large.

There are other additions and refinements which would be most welcome in any vectoring program because of the improvement they could guarantee. However, in the opinion of the present writer, there is one respect in which we may be grateful for the frugality imposed by ILLIAC upon the program described in R-74. It very beautifully enforced a principal which might be inadvertently jeopardized should time and capacity invite a more complex vectoring routine. One could unwittingly be tempted into the design of an interception control program which, with extreme efficiency as its goal, might in fact become critically sensitive to small errors in the measured parameters which were added for refinement. For tactical reasons, we should like to complete the interception at the earliest possible time unless certain other tactical considerations interfere. A program which makes use of reliable wind data would be superior, in this respect, to one which does not explicitly take account of windage. However, at the cost of flying somewhat longer paths, the latter program would prove to be the more reliable if the wind data showed inconstancy or inaccuracy. Unable to gather or use weather data, the JNS program calculates intercept vectors at frequent intervals on the basis of <u>present</u> positions and velocities, repeatedly correcting, albeit a few seconds late, for errors manifested in the last few seconds of flight. Somewhat longer flights result, but the eventual success of the interception is relatively insensitive to influences of wind, errors in tracking data, or pilot failure to respond instantly or accurately to vectoring commands.

<u>Logical Error</u>

The writer regrets to report that there is a logical error in the approximations which manifests itself whenever the angle FBC becomes small. The result of this error is sometimes merely awkward, sometimes painful, depending on FBC and the ratio of $\frac{1}{\alpha}$ to v_B. To illustrate the difficulty, imagine a head-on interception.



Recall that $\frac{1}{\alpha}$ is the assumed speed of the friend as used by ILLIAC. The pseudo-collision point which ILLIAC calculates is that point in front of B to which the bogey could fly during the time it would take for the friend to fly to the bogey's present position, B. When $v_B = \frac{1}{\alpha}$, the estimated collision point is at F, independent of the distance FB. Inasmuch as ILLIAC terminates its vectoring responsibility whenever range to the pseudo-collision point $\leq R_E$ (a pre-set parameter, usually set at ca. 10 miles) the interception for the case illustrated is considered finished, regardless of the distance FB which might still be very large.

Because an upper limit for v_B is more or less predictable and $\frac{1}{\alpha}$ is pre-settable it can usually be arranged that the pseudo-collision point will always fall in front of, rather than on or (even worse) behind the interceptor. This guarantees decent command headings to the friend but usually results in ILLIAC's sending an END-OF-INTERCEPT* message too early. About the best one can do within the framework of the present sub-routine is to select an α which makes $\frac{1/\alpha}{v_B}$ as large as possible without making $\frac{1/\alpha}{v_F}$ so large as to greatly

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* actually means "End of mid-course guidance; take over from here with A.-I. radar."

increase the occurrence of tail chases. If the expected speed advantage is in the ratio $\frac{600 \text{ Knots, Friend}}{400 \text{ Knots, Bogey}} = \frac{3}{2}$, one can fairly safely choose $\frac{1}{\alpha} = 800$. The pseudo-collision point for a head-on meeting will then lie half way between B and F, regardless of distance. If R_E is set to 10 miles, the END-OF-INTERCEPT will occur when the two planes are 20 miles apart. Setting R_E to 8, which is about the minimum safe value, will delay END-OF-INTERCEPT until the planes are 16 miles apart. The interceptor pilot will then fly 8 miles as expected, during which time he would be attempting to acquire and lock-on the bogey with his own A.I. radar. By the time he has flown 6 of the expected 8 miles, the bogey will have moved 4 miles, reducing the distance between the planes to $16 - (6 + 4) = 8$ miles. At about this time, lock-on should occur and final phase control initiated.

A substitute routine, designed by R. M. Brown of this laboratory has recently been inserted and is now undergoing tests. A supplement to the present report, containing some preliminary evaluation and opinion is planned for the near future, and may contain a description of the RMB substitution.

JNS Vectoring Summary

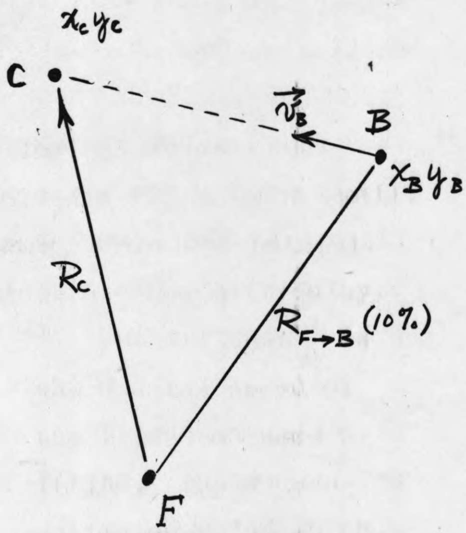
A thumbnail sketch of the sequence and nature of vectoring operations in the JNS program is given in what follows:

Any friendly object may be vectored. Infrequent, pursuit course vectors are provided for ships; frequent, pseudo-collision vectors for aircraft. Aircraft may receive automatic interception assignments and will be automatically vectored. A ship will be vectored only if manual intervention sets up the conditions. To cause a friendly ship to be vectored to any non-friendly object, merely insert the friend's ATN into the ATN digits of the non-friendly object. Artificial Strikees may be created for this purpose and can serve as static rendezvous points for two or more ships. A manual intervention into the appropriate ILLIAC Bank 2 word is necessary to undo this action.

Vectoring for air interceptions is performed as follows.

1. Assigned bogey, bearing ATN of a friend a/c, appears to ILLIAC on C.P. (Clear Picture)

2. ILLIAC extracts $x_B y_B z_B \dot{x}_B$ and $\dot{y}_B$ and plants them in friend's ILLIAC mission bank.



3. Friend appears on C.P., marked as assigned for vectoring.

4. ILLIAC reaches into mission bank, unpacks $x_B y_B z_B \dot{x}_B$ and $\dot{y}_B$ and begins vector calculation.

5. $R_{F \to B}$ (friend-to-bogey) is calculated.

6. True collision point coordinates $x_c y_c$ would be given by

$$x_c = x_B + \dot{x}_B t^*$$

$$y_c = y_B + \dot{y}_B t^*$$

where t^* is time required to fly R_c.

Collision coordinates are approximated by $x_m y_m$

$$x_c \cong x_m = x_B + \dot{x}_B \alpha R_{F \to B}$$

$$y_c \cong y_m = y_B + \dot{y}_B \alpha R_{F \to B}$$

using fixed α to approximate $\frac{1}{v_F}$.

7. Range and bearing from friend is calculated to $x_c y_c$, using 1 % approximation for range.

$$1\,\%\ R = |\Delta x| + |\Delta y| - \frac{|\Delta x|\,|\Delta y|}{7/8\,(|\Delta x| + |\Delta y|)}$$

Θ (≡ bearing to mission point) is given in 256^{ths} of a circle, called Semi-Snyds.

1 Kypta = 1 Snyd = $\frac{1}{128}$ of a circle = $\frac{\pi}{64}$ radians.

8. Vector command is output via discrete address channel to friend. Calculation and broadcasts occur once each clear picture frame. Vectoring message contains Θ_c and R_c but not $R_{F \to B}$. See Appendix for message forms.

CAP and Steer Vectoring

In addition to interception control, provision is made in the JNS vectoring routines for supplying navigation data to a friendly aircraft to assist it in reaching and maintaining a patrol station or to return it to a carrier. In both cases the information received by the aircraft identifies the type of mission (CAP vector vs. Return to Carrier) and supplies the bearing and distance to the mission reference point.

For friendly aircraft, the clear picture digits S_1S_2 designate the present mission of the aircraft. ILLIAC always reads these digits in order to determine what type of processing is required. The interpretations placed on the configurations of S_1S_2 are:

00 $\hat{=}$ CAP
01 $\hat{=}$ INTERCEPT
10 $\hat{=}$ STEER
11 $\hat{=}$ STEER CRITICAL

When an aircraft is designated as being on CAP ($S_1S_2 = 00$) it is recognized by ILLIAC as available for weapon assignment. In giving it an assignment, ILLIAC will change S_1S_2 from 00 $\hat{=}$ CAP to 01 $\hat{=}$ INC. This particular operation is, more truly, merely the setting of $S_2 \rightarrow 1$ and is the only change ILLIAC can make in those digits. CAP and STEER are missions which can only be made by hand.

CAP Vectoring

At the time of initial loading into ILLIAC's weapon banks, all friendly aircraft are semi-permanently marked according to the type of combat air patrol they should fly if ever assigned to CAP. Two types of combat air patrol are recognized by the Snyder program and are characterized by the nature of their patrol stations. They are colloquially called "Carrier CAP" and "Georef CAP". The latter class flies a patrol orbit through or about a fixed map point while the former flies an orbit which bears some particular relation to its home carrier.

Carrier CAP is very flexible in the nature of the sequence of missions it can be given. Without recourse to intervention into the program it is possible to give a Carrier CAP aircraft successive missions of CAP, INTERCEPT, and STEER in any order or sequence.

Georef CAP, on the other hand, is not so flexible. The coordinates of the georef point to which its CAP station is related occupy, in the mission bank (B1 and B2) words, the space allotted to the mission coordinates x_M and y_M. If the mission is georef CAP, $x_M = x_{GR}$ and $y_M = y_{GR}$. If the mission is an interception with collision point x_c y_c then $x_M = x_c$ and $y_M = y_c$. When a georef CAP is placed on an intercept mission, the CAP reference coordinates $x_{GR} y_{GR}$ become destroyed when over-written by the new mission coordinates x_c y_c and the aircraft cannot be returned to CAP simply by undoing the weapon assignment and changing $S_1 S_2$ back to 00.

The difference in flexibility between Carrier CAP and georef CAP resides in the fact that the home carrier coordinates are never stored in the locations x_M y_M in the mission banks. Whenever ILLIAC requires $x_{carrier}$ $y_{carrier}$, as it does for Carrier CAP or for STEER (home), it consults the aircraft's B1 word for the ATN of the home carrier and, using this to compute the address, looks up the carrier's C1 word wherein is stored the up-to-date $x_{carrier}$ $y_{carrier}$. As long as the home carrier ATN remains in the aircraft's B1 word, its coordinates can always be ascertained and used for Carrier CAP or STEER (home) vectoring.

Steer Vectoring

For use in these discussions the word STEER is to be interpreted as "return-to-home-carrier". The coordinates to which a plane is to be steered are never confounded by any previous mission coordinates (except STEER CRITICAL. See below) so the changes in assignment,

CAP (georef or carrier) $\rightarrow$ STEER ,

or INC $\longrightarrow$ STEER

can always be made simply by setting $S_1 S_2 \rightarrow 10$. When the clear picture word of a friendly aircraft with $S_1 S_2 = 10$ enters ILLIAC, the computer looks up the home carrier's C1 bank word, extracts $x_{carrier}$ $y_{carrier}$, computes $\theta_{to\ carrier}$ and $R_{to\ carrier}$, and transmits these to the plane's discrete address receiver. It also notifies it to "go home" and indicates the "gate" or prescribed approach window.

If, in the first pass through the computer after S_1S_2 has been set to STEER, the home carrier is found to be "not receiving", ILLIAC will automatically change $S_1S_2 \rightarrow 11$ and will execute a STEER CRITICAL processing, directing the aircraft to the nearest carrier able to receive him. STEER CRITICAL may also be instituted manually if the plane was never previously on STEER.

Mission Sequencing

Without manual intervention into ILLIAC's memory banks the following sequences of missions may be executed for friendly aircraft.

Planes designated for possible georef CAP can go from

$CAP_{GR} \rightarrow$ INC, $CAP_{GR} \rightleftarrows$ STEER, or $CAP_{GR} \rightleftarrows$ STEER CRIT. (if never previously on STEER).

They can also go from

INC $\rightleftarrows$ STEER or INC $\rightleftarrows$ STEER CRIT. (if never previously on STEER),

But they cannot return to CAP_{GR} from INC.

Planes designated for possible Carrier CAP can go from

CAP $\rightleftarrows$ INC, CAP $\rightleftarrows$ STEER, or CAP $\rightleftarrows$ STEER CRIT. (if never previously on STEER),

and can also go from

INC $\rightleftarrows$ STEER, INC $\rightleftarrows$ STEER CRIT. (if never previously on STEER).

Both types of planes are subject to the following STEER rules. Once on STEER, no matter what other missions may be successively substituted, they can never go to STEER CRITICAL. The only ways to STEER CRITICAL are:

1. If never before on STEER, plane can be manually placed on STEER CRITICAL.
2. If never before on STEER, plane can automatically go to STEER CRITICAL on first frame following assignment to STEER, if ILLIAC discovers STEER improper because home carrier not receiving. This is the only automatic mission assignment other than interception.

OBJECT CLASS CHARACTERISTICS

UHP Aircraft

0000
0100
1000

These are the only objects which are automatically threat-evaluated and automatically weapon-assigned. Except for having possibly unequal thresholds T_{0000th}, T_{0100th}, T_{1000th}, for weapon assignment, they are treated alike by ILLIAC. Any unidentified object, regardless of velocity, automatically has the classification 0000 = unidentified aircraft.

To cause an automatic weapon assignment to occur <u>now</u> instead of <u>later</u>,

$$\text{change} \left\{\begin{array}{l}\text{UNID.}\\ \text{HOST.}\\ \text{PROB.F.}\end{array}\right\} \text{ aircraft's Threat Number to } \left(\begin{array}{c}T_{0000}\\ T_{0100}\\ T_{1000}\end{array}\right) \text{ respectively.}$$

To effect a manual weapon assignment to weapon whose ATN = N_o, replace T_{Bogey} with N_o and set bogey's $S_1 \rightarrow 1$. If the assigned friend is a gun (platform), set bogey's $S_3 \rightarrow 1$; if the assigned friend is a plane, set friend's $S_1 S_2 \rightarrow 01$.

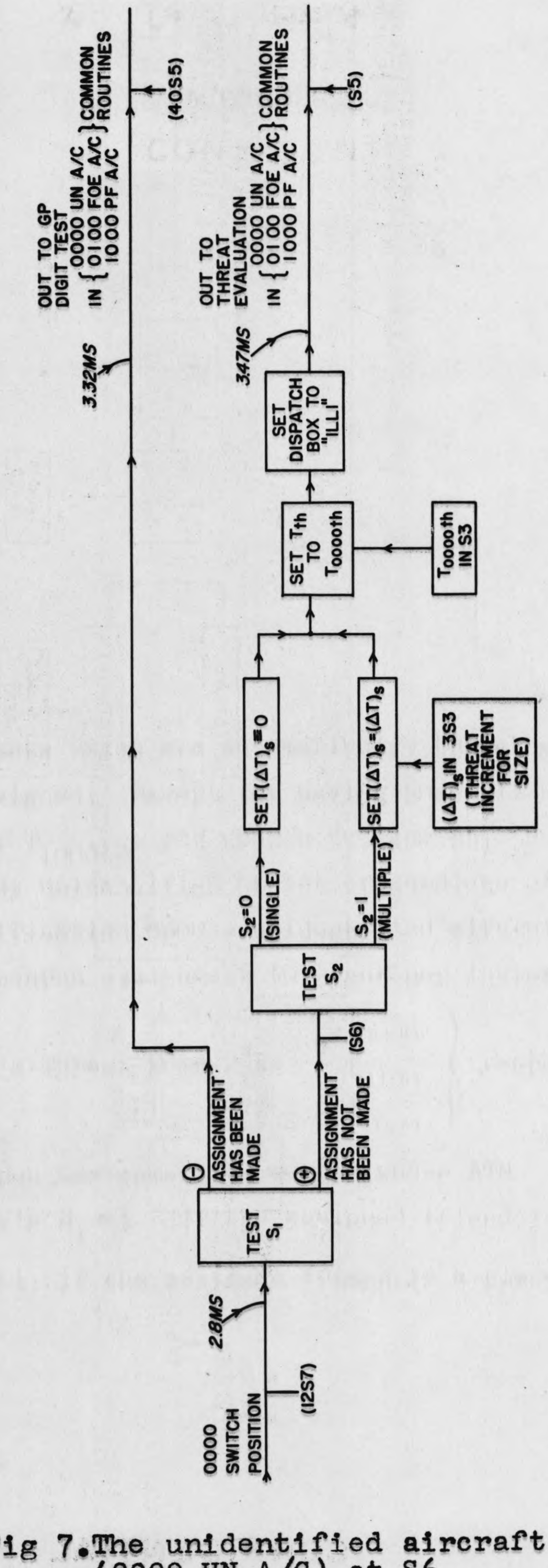


Fig 7. The unidentified aircraft routine (0000 UN A/C) at S6.

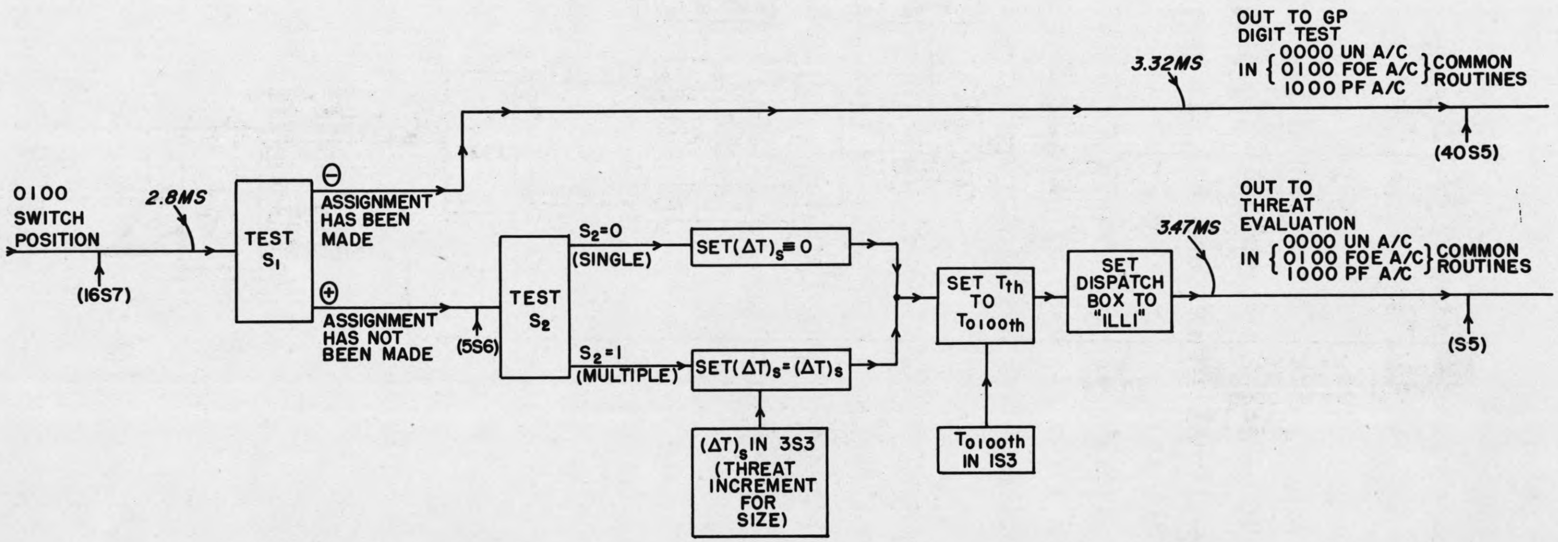


Fig 8. The foe aircraft routine (0100 foe A/C) at 5S6.

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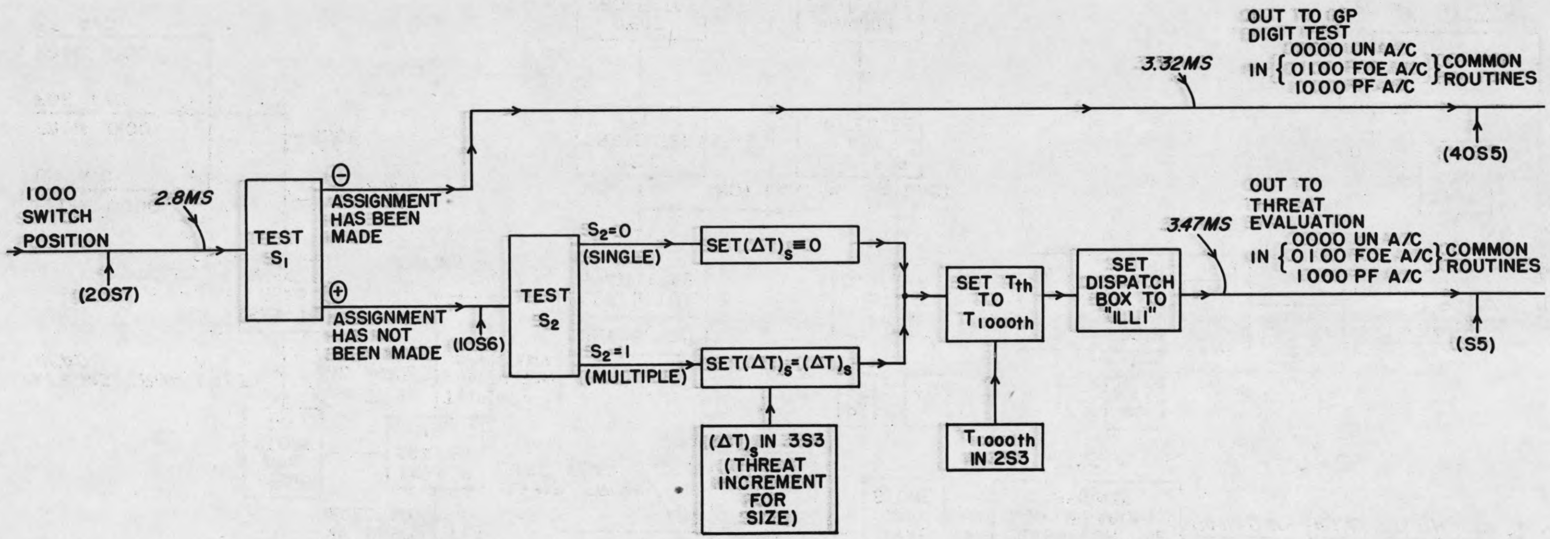

FIG. 9 THE PROBABLE FRIEND AIRCRAFT ROUTINE (1000 PF A/C) AT 10S6

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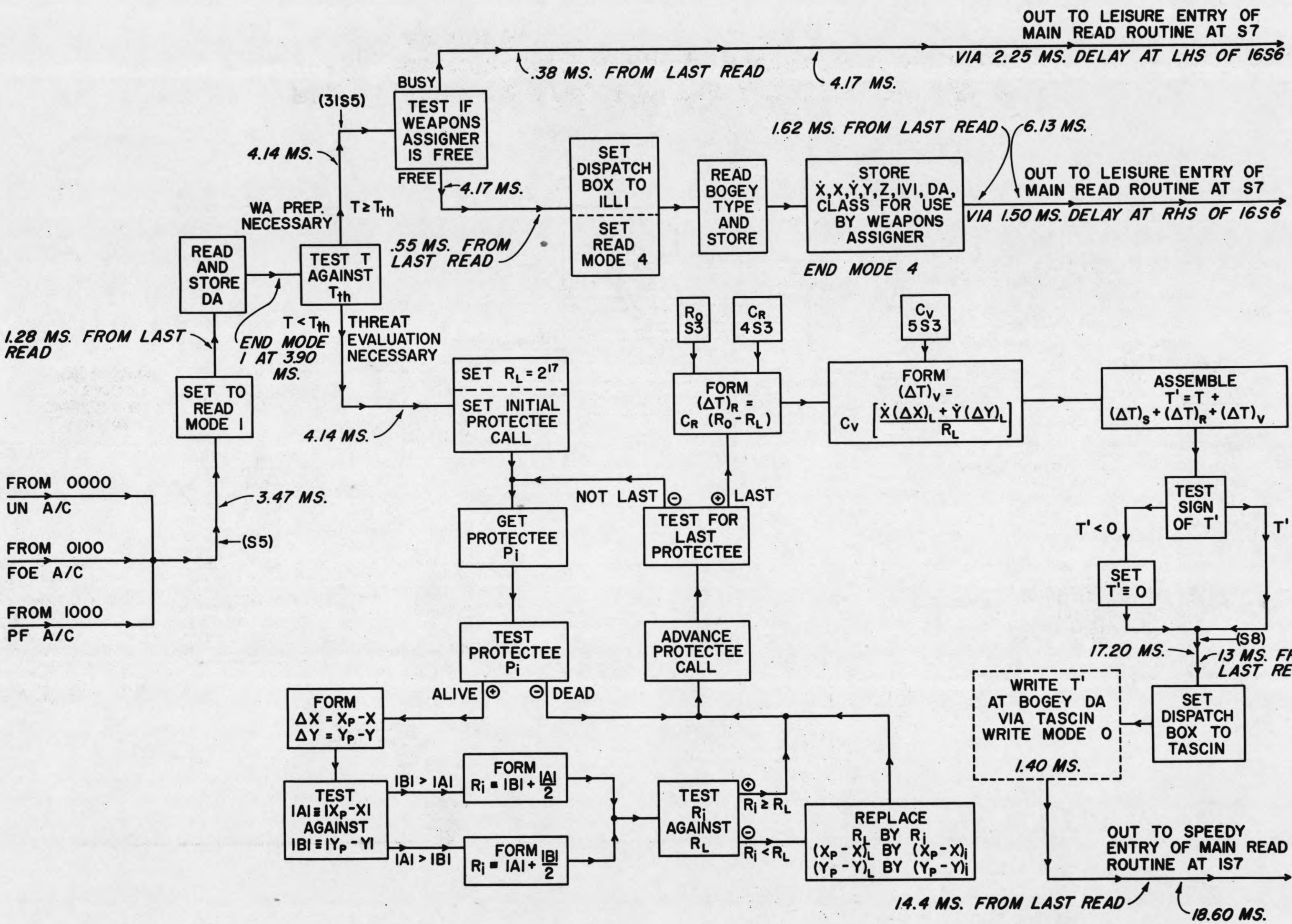

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FIG. 10 0000 UN A/C, 0100 FOE A/C, 1000 PF A/C COMMON ROUTINES AT S5 (THREAT EVALUATOR)

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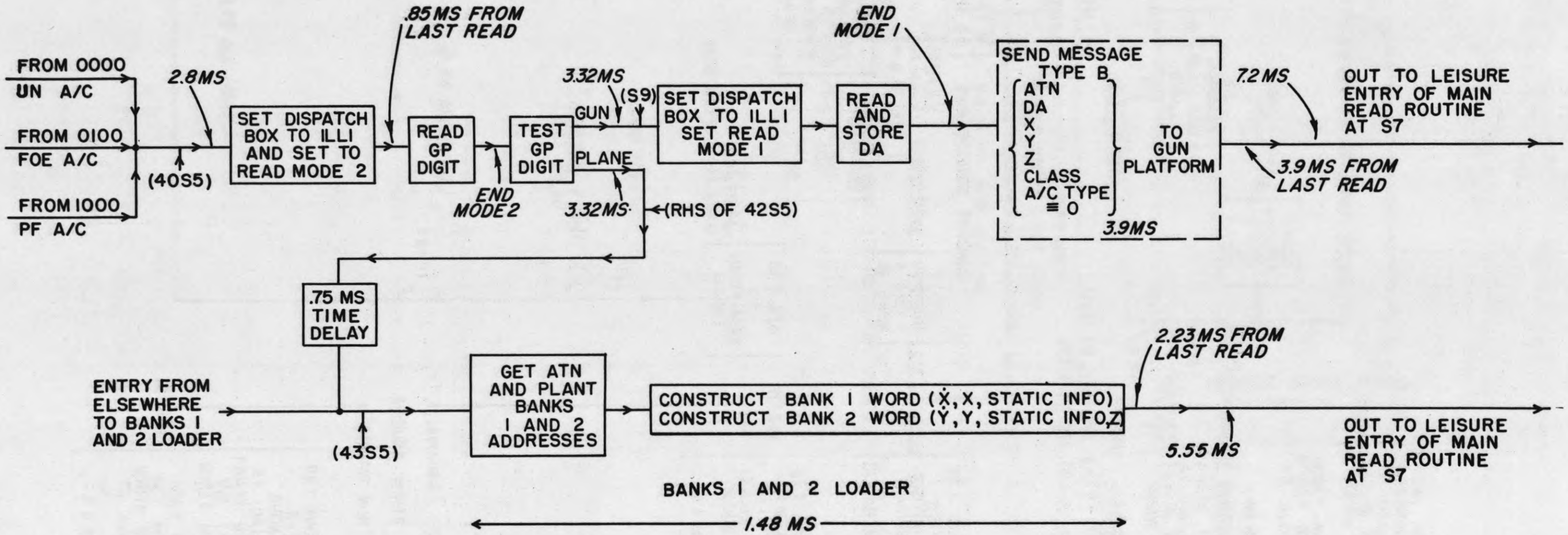

Fig 11.0000 UN A/C, 0100 Foe A/C, 1000 PF A/C common post weapons assignment routine at 40S5.

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<u>UHP-Ship, UH-Sub</u>

0001
0101
1001
0010
0110

These five classes are treated identically by ILLIAC. They are not threat-evaluated. If their ATN = 0 they are ignored. If they are manually given an ATN $\neq$ 0 belonging to any friendly object, ILLIAC will store their up-to-date x, y, $\dot{x}$ and $\dot{y}$ in the friend's mission bank words, and will vector the friend.

UHP-Ship, UH-Sub
routines, next page.

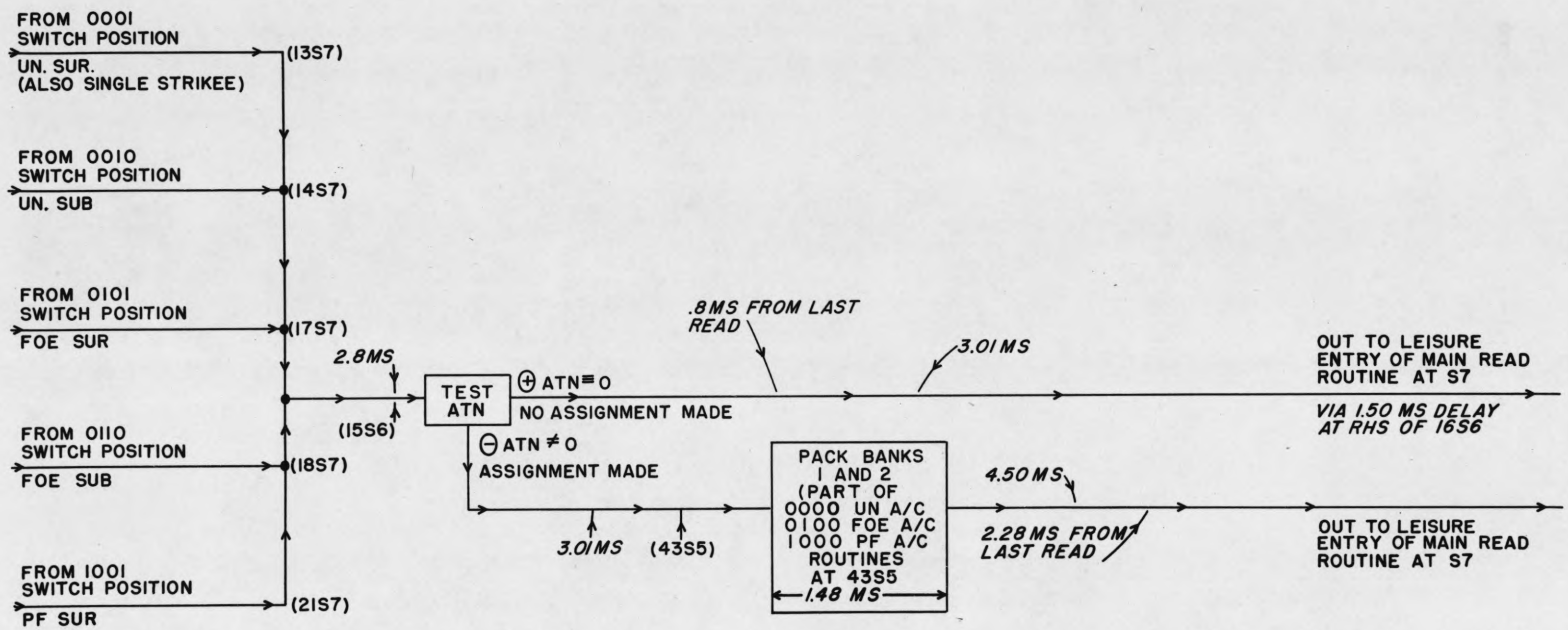

FIG. 12 TREATMENT OF SLOWLY MOVING HOSTILE CLASSES AT 15S6

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Strikee

0111

Strikees may be either legitimate strike targets or, when specially marked, merely FRAME END MARKS. The non-FRAME-MARK Strikee is treated identically with UHP-Ship or UH-Sub with one important exception: two friend's may be vectored toward it.

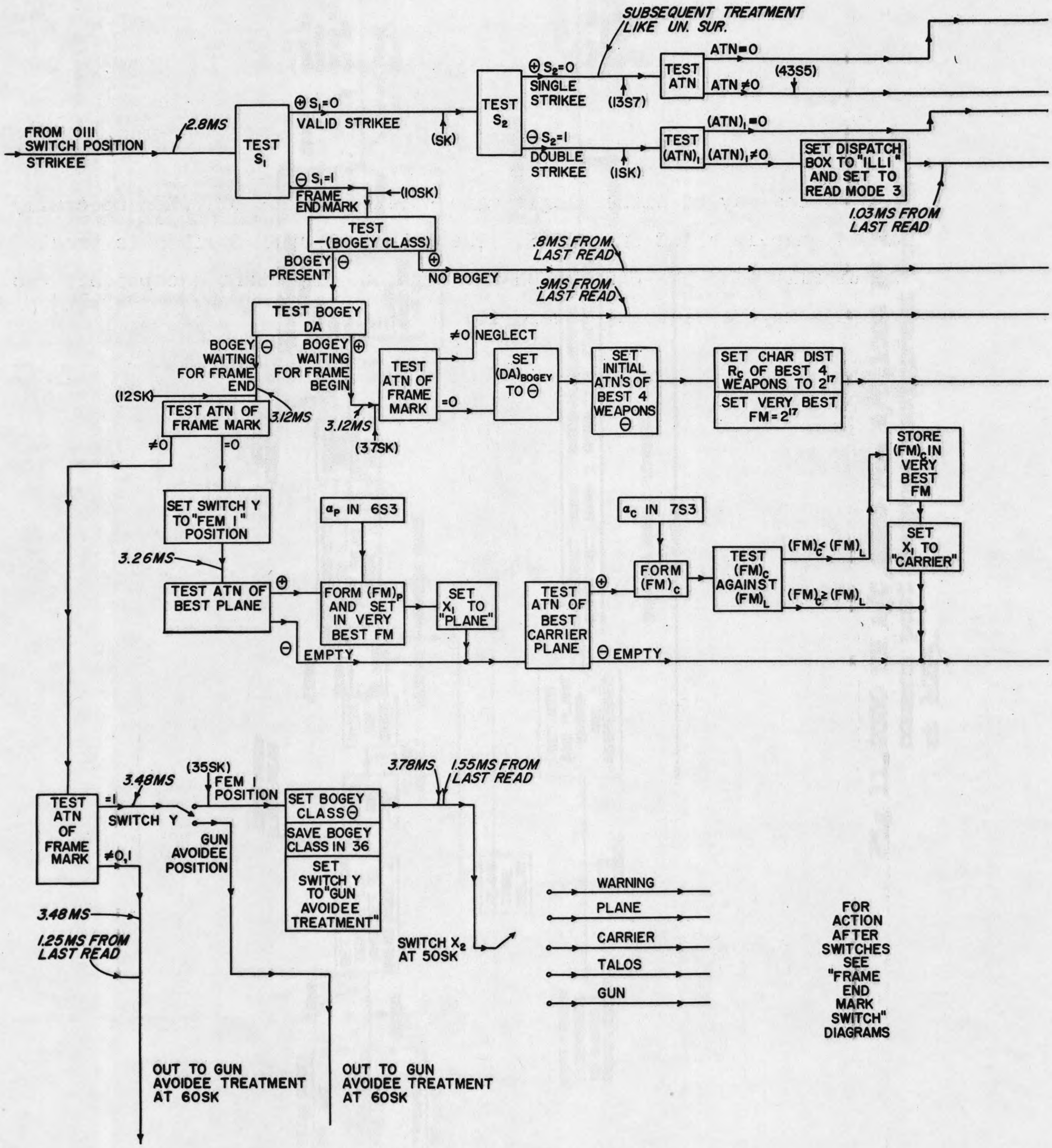

Fig 13. Strikee (0111), Frame mark, and weapons assignment routines at SK.

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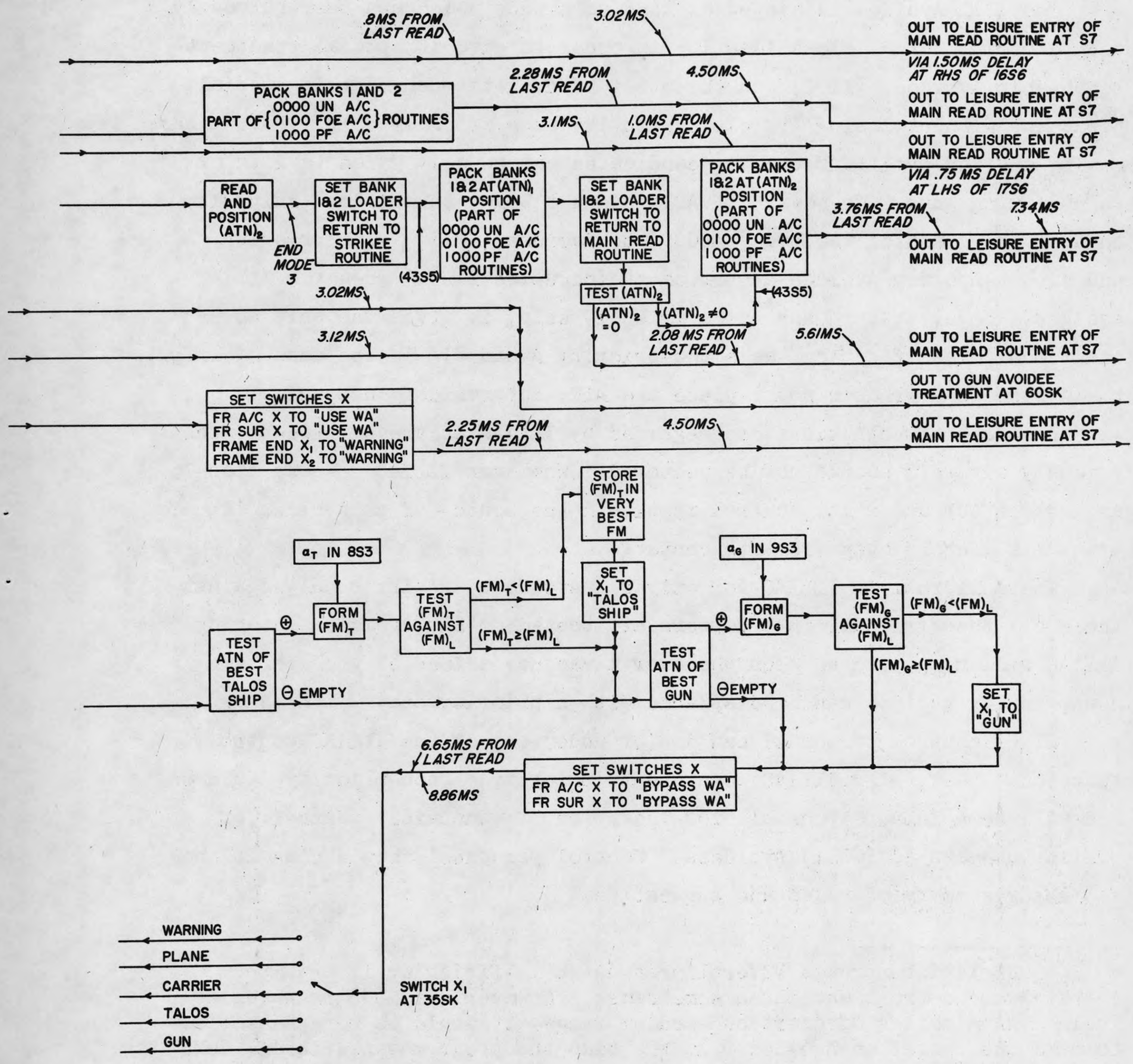

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Avoidee

0011 and F-ship 1101 with $S_2 = 1$

The 0011 Avoidee is a special kind of object which has been purposely robbed of its normal class identity in order to give it special treatment. The F-ship Avoidee, (1101), on the other hand, gets much of this special treatment without losing its class identity as a friendly ship. Both kinds can be created by ILLIAC but the candidates can be only Talos targets or ships firing guns. Whenever ILLIAC assigns a bogey to a Talos (ship) it changes the class of the bogey (0000) to Avoidee (0011), with priority, and with temporary Avoidee number of 64 (occupies ATN). Whenever ILLIAC assigns a bogey to the Guns* of a friendly ship, it gives the ship an additional classification, as a non-priority Avoidee. In the case of ships, the Avoidee number does not replace the ATN, but resides in $S_4S_5S_6$.

Avoidees of both kinds are regarded by ILLIAC as areas through which friendly aircraft should not be vectored. Whenever ILLIAC detects that an interceptor under its control is within the bounds of an Avoidee, it transmits vectors away from its center.

There is room in ILLIAC for only six Avoidees and it is only against these six that friendly interceptors are tested; other Avoidees entering ILLIAC will be stored as such whenever a vacancy arises or whenever a non-priority Avoidee can be displaced with a priority one.

Since control personnel can do (or undo) any of the ILLIAC control functions, they, like ILLIAC, can create priority or non-priority Avoidees and will be solely responsible for insertion of mountains, weather, or similar objects as (0011) Avoidees. Control personnel should consult the following summary of rules and suggestions.

---

* If GUNS is interpreted literally as AA shell-firing artillery, the F-ship Avoidee treatment makes some sense. However, if GUNS is taken to include AA missiles of short and medium range, it would be more sensible to make the target an Avoidee. At the time the program was written, GUNS were interpreted literally and the reader is invited to bear in mind that the principal goal of the program was to demonstrate some of the kinds of control functions that could be performed. It is to be considered more as an exhibition than as a recommended model.

Summary of Meanings and Suggested Usage for Avoidee Numbers ($A^{\#}$'s) in JNS Program.

Avoidee (0011): ATN $\equiv A^{\#} = 0, \ldots\ldots, 127$

F-ship Avoidee (1101 with $S_2 = 1$): ATN $\not\equiv A^{\#}$

$A^{\#} = 0, \ldots\ldots, 7$

and may duplicate $A^{\#}$'s already in use for (0011) Avoidees.

0011 Avoidee		F-ship Avoidee 1101 with $S_3 = 1$	
if $A^{\#} = 0$	ILLIAC ignores	$A^{\#} = 0$	ILLIAC ignores
$A^{\#} = 1, \ldots 6$	ILLIAC has in storage	$A^{\#} = 1, \ldots 6$	ILLIAC has in storage
$A^{\#} = 7$	ILLIAC has bounced it. Is non-priority	$A^{\#} = 7$	Bounced from storage by ILLIAC
		or	New Gun WA
		or	Manually created
$7 < A^{\#} < 64$ or $64 < A^{\#} < 127$	Manually created; not yet stored in ILLIAC Avoidee banks. DO NOT USE THESE NUMBERS EXCEPT 8. See below.	$7 < A^{\#}$	Impossible; only 3 digits available.
$A^{\#} = 8$	New. Manually created.		
$A^{\#} = 64$	New. Priority. ILLIAC created. TALOS TARGET		
$A^{\#} = 127$	Priority Avoidee for which ILLIAC has no storage space		

$A^{\#}$S shown here are in decimal notation. For insertion via Keyset and for reading Clear Picture, use sexadecimal.

continued, (over)

When ILLIAC assigns a bogey (0000) to TALOS it changes the bogey to priority Avoidee (0011) ($S_1 = 1$) with ATN $\equiv A_o = 64$. On the next pass through ILLIAC, this Avoidee (DA, x, y, priority) will be stored in Avoidee location $6 \geq A_1 \geq 1$ if possible, whereupon the ATN $\equiv A_o = 64$ will give way to ATN $= A_1$. If no storage address is available, ATN $\equiv A_o = 64$ will give way to ATN $\equiv A_1' = 127$ until storage space is found.

To make a manual Talos assignment, Set bogey's class→0011 (Avoidee), bogey's ATN→64 (=40 sexad.)(use "Bogey paired with 'P'" switch, which sets), bogey's S_1→1 (priority).

To create a non-priority (0011) Avoidee, Set class→0011, ATN→8 (using F-ATN switch which sets $S_2 = 0$, non-priority), Δx and Δy, K = 1.

To cause an F-ship to become an Avoidee Set $S_2 = 1$ and ATN = 7 (using F-ATN switch).

To erase an Avoidee set S_3→1. This causes erasure from both ILLIAC and TASC. If the track has already died in TASC before manual erasure via S_3, it can be removed from ILLIAC <u>only if original drum address is known</u>. <u>Therefore, keep a log of DA vs. $A^{\#}$ during any exercise</u>.

(Avoidee routines, overleaf)

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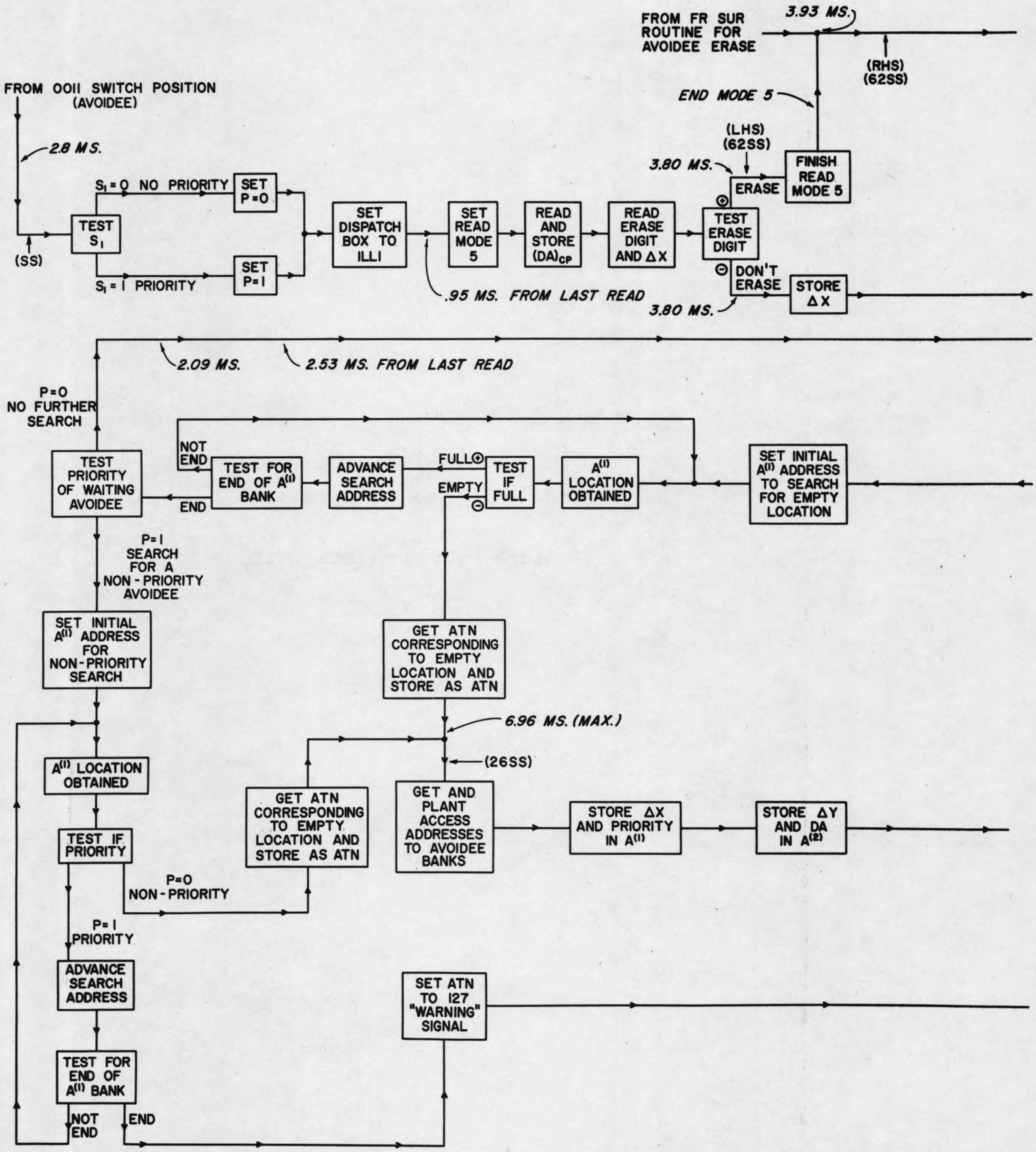

FIG. 14 THE AVOIDEE ROUTINES (0011) AT SS

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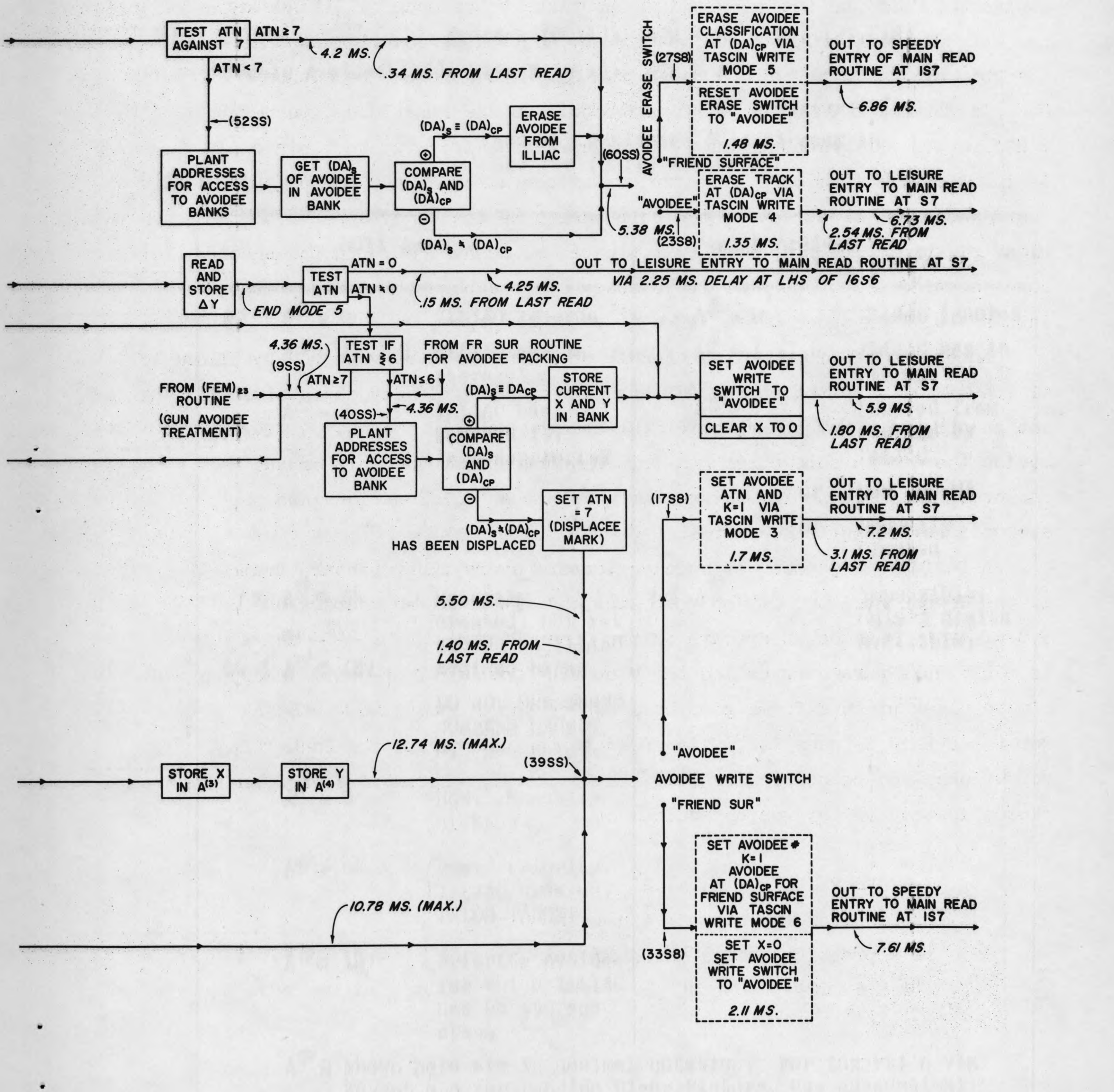

TEST ATN AGAINST 7
ATN ≥ 7
4.2 MS.
.34 MS. FROM LAST READ
ATN < 7
(52SS)
PLANT ADDRESSES FOR ACCESS TO AVOIDEE BANKS
GET $(DA)_S$ OF AVOIDEE IN AVOIDEE BANK
COMPARE $(DA)_S$ AND $(DA)_{CP}$
$(DA)_S \equiv (DA)_{CP}$
ERASE AVOIDEE FROM ILLIAC
$(DA)_S \not\equiv (DA)_{CP}$
(60SS)
5.38 MS.
AVOIDEE ERASE SWITCH
(27S8)
ERASE AVOIDEE CLASSIFICATION AT $(DA)_{CP}$ VIA TASCIN WRITE MODE 5
RESET AVOIDEE ERASE SWITCH TO "AVOIDEE"
1.48 MS.
"FRIEND SURFACE"
OUT TO SPEEDY ENTRY OF MAIN READ ROUTINE AT IS7
6.86 MS.
"AVOIDEE"
(23S8)
ERASE TRACK AT $(DA)_{CP}$ VIA TASCIN WRITE MODE 4
1.35 MS.
OUT TO LEISURE ENTRY TO MAIN READ ROUTINE AT S7
6.73 MS.
2.54 MS. FROM LAST READ
READ AND STORE ΔY
END MODE 5
TEST ATN
ATN = 0
ATN ≠ 0
4.25 MS.
.15 MS. FROM LAST READ
OUT TO LEISURE ENTRY TO MAIN READ ROUTINE AT S7
VIA 2.25 MS. DELAY AT LHS OF 16S6
4.36 MS.
(9SS)
ATN ≥ 7
TEST IF ATN ≷ 6
ATN ≤ 6
FROM FR SUR ROUTINE FOR AVOIDEE PACKING
FROM $(FEM)_{23}$ ROUTINE
(GUN AVOIDEE TREATMENT)
(40SS)
4.36 MS.
PLANT ADDRESSES FOR ACCESS TO AVOIDEE BANK
COMPARE $(DA)_S$ AND $(DA)_{CP}$
$(DA)_S \equiv DA_{CP}$
STORE CURRENT X AND Y IN BANK
$(DA)_S \not\equiv (DA)_{CP}$
HAS BEEN DISPLACED
SET ATN = 7 (DISPLACEE MARK)
SET AVOIDEE WRITE SWITCH TO "AVOIDEE"
CLEAR X TO 0
OUT TO LEISURE ENTRY TO MAIN READ ROUTINE AT S7
5.9 MS.
1.80 MS. FROM LAST READ
(17S8)
SET AVOIDEE ATN AND K=1 VIA TASCIN WRITE MODE 3
1.7 MS.
OUT TO LEISURE ENTRY TO MAIN READ ROUTINE AT S7
7.2 MS.
3.1 MS. FROM LAST READ
5.50 MS.
1.40 MS. FROM LAST READ
"AVOIDEE"
STORE X IN $A^{(3)}$
STORE Y IN $A^{(4)}$
12.74 MS. (MAX.)
(39SS)
AVOIDEE WRITE SWITCH
"FRIEND SUR"
SET AVOIDEE # K=1 AVOIDEE AT $(DA)_{CP}$ FOR FRIEND SURFACE VIA TASCIN WRITE MODE 6
SET X=0 SET AVOIDEE WRITE SWITCH TO "AVOIDEE"
2.11 MS.
(33S8)
OUT TO SPEEDY ENTRY TO MAIN READ ROUTINE AT IS7
7.61 MS.
10.78 MS. (MAX.)

Friend Ship (Surface) and Friend Subsurface
(1101) (1110)

Of these two classes only (1101) can receive an automatic weapon assignment, and the assignments will continue to be made by ILLIAC to the friendly ship only so long as $S_1 = 1$; control personnel must make the ship available or not available via S_1. The ship can be either a GUN platform or a TALOS ship but not both. In the first case, whenever a GUN weapon assignment is made on an intruding aircraft, the ship's ATN is inserted into the threat number box of the aircraft and the bogey's coordinates are broadcast to the ship each time the bogey appears on the clear picture. The ship itself is treated as an Avoidee. In the second case, a TALOS ship, whenever it is assigned to a bogey, the bogey is made into an (0011) Avoidee whose ATN = $A^{\#} \neq ATN_{TALOS\ SHIP}$

An object of either class, F-Ship or F-Sub, will be vectored by ILLIAC if its ATN is inserted in the ATN box of some non-friendly object (usually not an aircraft.) The mission can be changed readily enough, by simply moving the ATN to some other non-friendly object but the ship or sub cannot be returned to "do-not-vector" without an intervention into the appropriate ILLIAC Bank 2 word.

A Surface Ship does not receive vectors every clear picture frame if the Weapon Assigner is "on" but, instead, it receives vectors one out of every P times it appears on the Clear Picture. $P = \frac{1024}{K}$ and K is a settable parameter called the Vectoring Counter Increment. Every time a clear picture frame goes by in which there occurs no vectoring for the F-Ship in question, K is added to the counter in the Bank 1 word. When the count reaches 1024, the vectoring alternative will be chosen instead of any weapon assignment.

$0 \leq K \leq 2^{39} + 2^{38} + \ldots . 2^0$
But 1024 in the counter causes vectoring, so a practical range for K is
$0 \leq K \leq 1024$

continued next page

If K = 16, vectoring occurs once out of 64 frames.

32,	....	32
64,	....	16
128,	....	8
256,	....	4
512,	....	2

1024, vectoring occurs every appearance; no WA ever occurs for this ship.

(Friend Surface routines, overleaf)

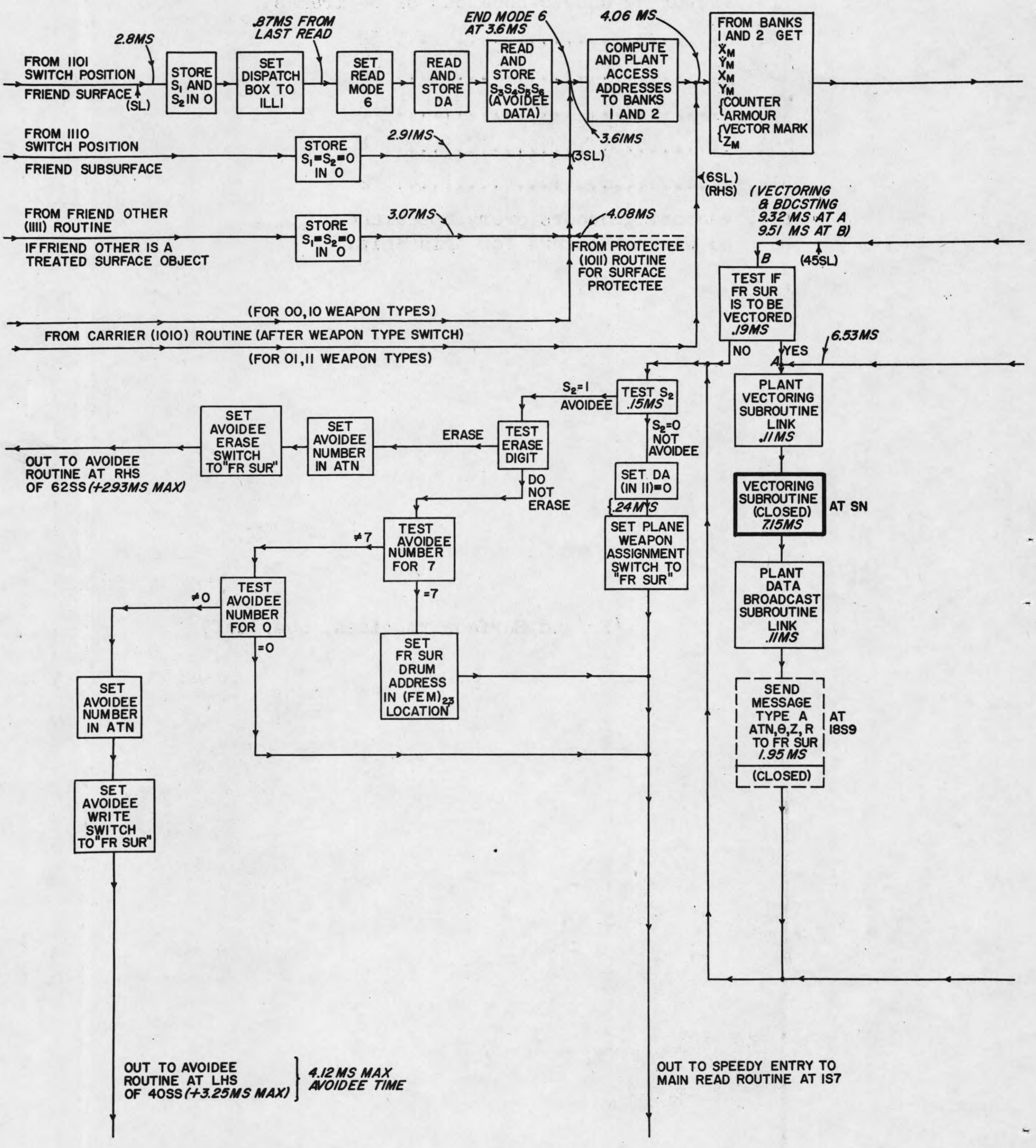
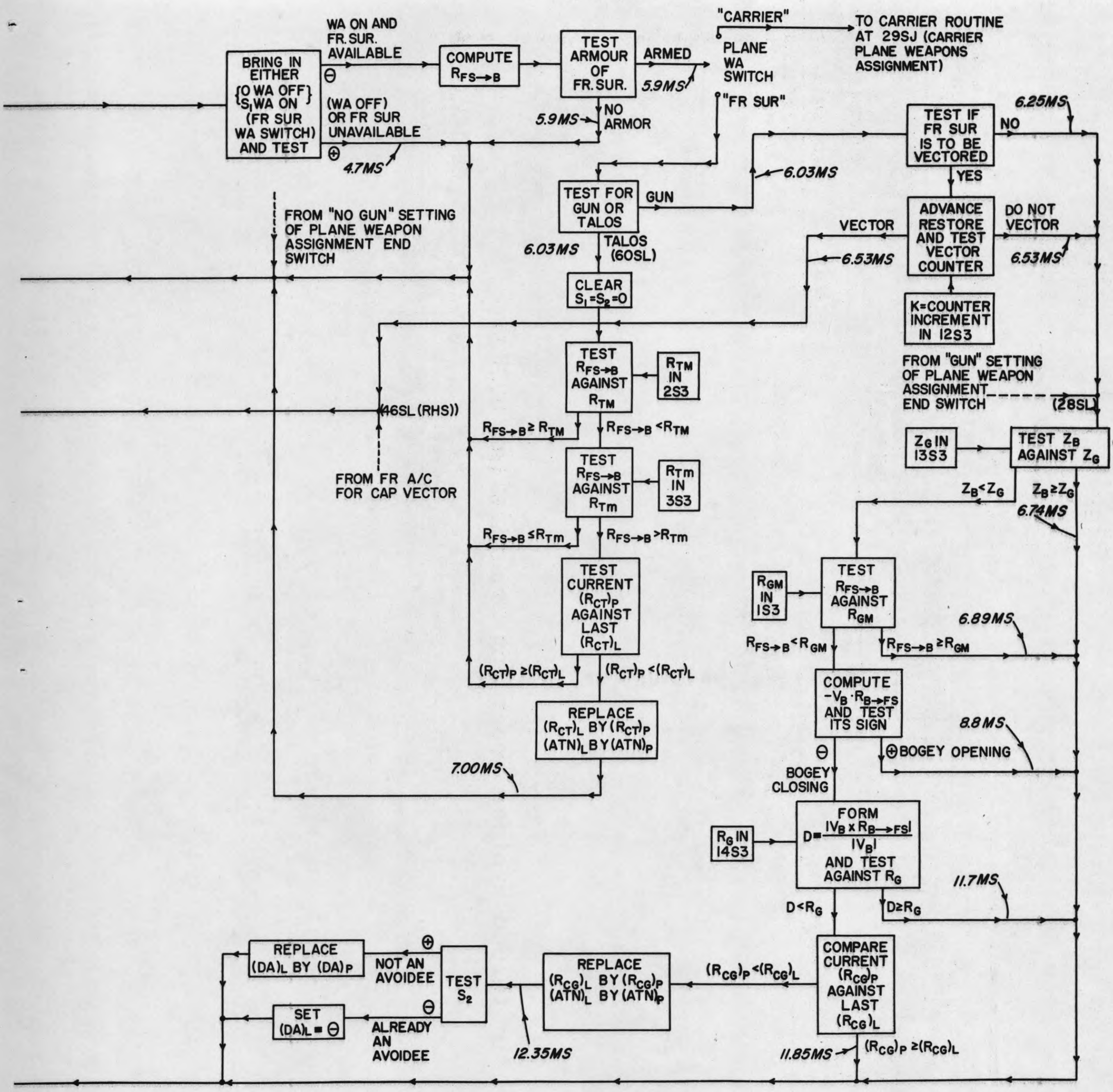


Fig 15. Friend surface routines (1101) at SL.



MAX TIMES:
(TALOS:-WA-VECTOR-NO AVOIDEE = 16.90 MS MAX)
(GUN:-WA-AVOIDEE = 16.47 MS MAX)
(GUN:-VECTOR-AVOIDEE = 19.97 MS MAX)
FRIEND SUBSURFACE
4.58MS MIN (2.35MS FROM LAST READ)
13.90MS MAX

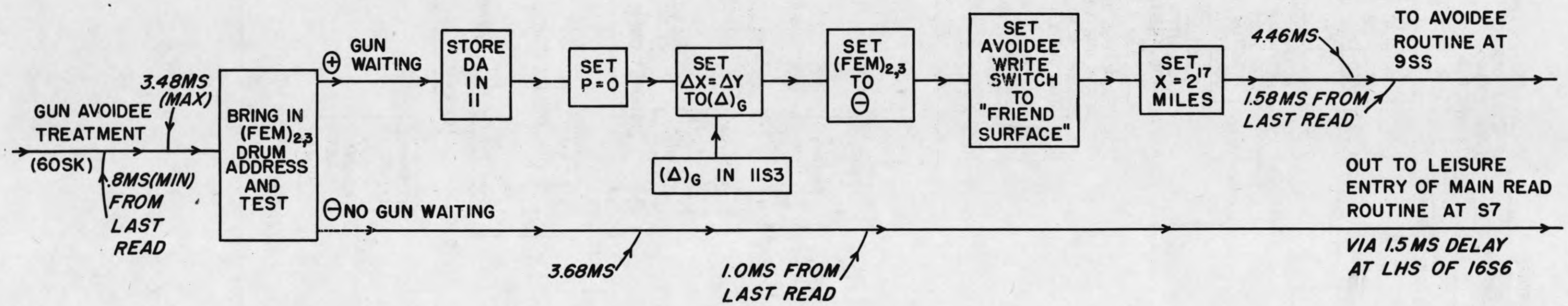


Fig 16. Gun avoidee treatment routine (at 60SK).

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Carrier

(1010)

Aircraft carriers are treated by the JNS Program at a level of sophistication considerably above that for Friend-Surface (1101) class. They may be vectored, receive fun assignments, furnish aircraft for carrier plane assignments, receive (returning) aircraft on STEER and, if so marked, be treated as Protectees. They can never be Talos ships nor Avoidees.

Control personnel should heed the following facts and admonitions:

1. Mission Bank 1 word of any carrier must indicate carrier has guns even if it really has none available. Without these Bank 1 marks it can never get a carrier plane WA. Availability or lack of guns should be indicated solely by digit S_7.
2. When $S_7 = S_8 = 1$ (Guns and Planes available) carrier never gets vectored while Weapon Assigner is on.
3. The CP Bank word in ILLIAC is 40 digits in 5 blocks of 8; each block is a carrier plane ATN plus a zero spacer. As these planes are weapon-assigned they are shifted out the left end of the register while zeros are shifted in at the right hand end. When the left-most block of 8 becomes all zeros ILLIAC considers the carrier "empty". Therefore, do not put a plane with ATN = 0 in a carrier, for neither it nor any plane following it (to the right) will ever receive a Carrier Plane Weapon Assignment.
4. A Protectee Carrier must have $1 \leq \text{ATN} \leq 4$. Non-protectees carriers may have $1 \leq \text{ATN} \leq 8$ but carriers 1-4 soak up the Protectee addresses except for georef Protectees. i.e. can have both Carrier ATN = 2 and georef Protectee ATN = 2.

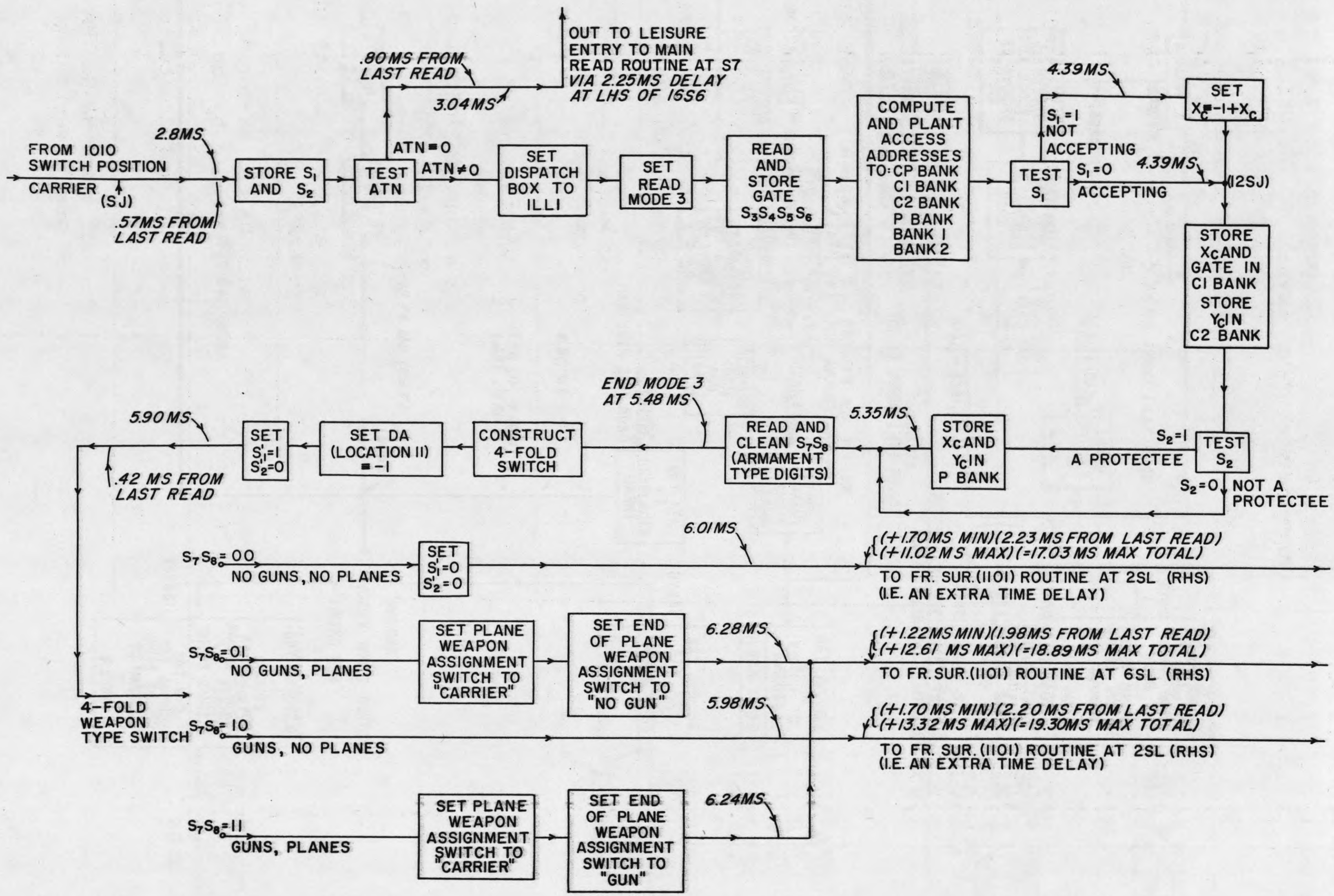

Fig 17. Carriers routines (1010) at SJ.

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Weapons Assignment Switch Setting	Clear Picture Word Carrier Weapon Digits S_7 S_8	Armament Digits in Carriers Bank 1 ILLIAC Storage Word	Computer Action with Respect to Vectoring and Weapons Assignment
WA Switch "OFF" (No Bogey)	any	any	Vectoring (if indicated by Bank 2)
WA Switch "ON" (BOGEY)	0 No Guns, 0 No Planes	any	Vectoring (if indicated by Bank 2)
	0 No Guns, 1 Planes	0 0 Unarmed	Vectoring (if indicated by Bank 2)
		0 1 Gun or	Plane WA - and vectoring (if indicated by Bank 2) if Plane WA goes through less than 5 of its steps Plane WA - No vectoring (even if indicated by Bank 2) if Plane WA goes through its 5th step
	1 Guns, 0 No Planes	0 0 Unarmed	Vectoring (if indicated by Bank 2)
		0 1 Gun	Gun WA P-1 out of P appearances Vectoring (if indicated by Bank 2) 1 out of P appearances Gun WA every time if "no vectoring" indicated by Bank 2
		1 0 1 1 } TALOS	TALOS WA and vectoring (if indicated by Bank 2)
	1 Guns, 1 Planes	0 0 Unarmed	Vectoring (if indicated by Bank 2)
		0 1 Gun or 1 0 1 1 TALOS	Carrier Plane WA-Gun WA (each time) (vectoring never)

Figure 18 - Weapons Assignment Rules for Carrier

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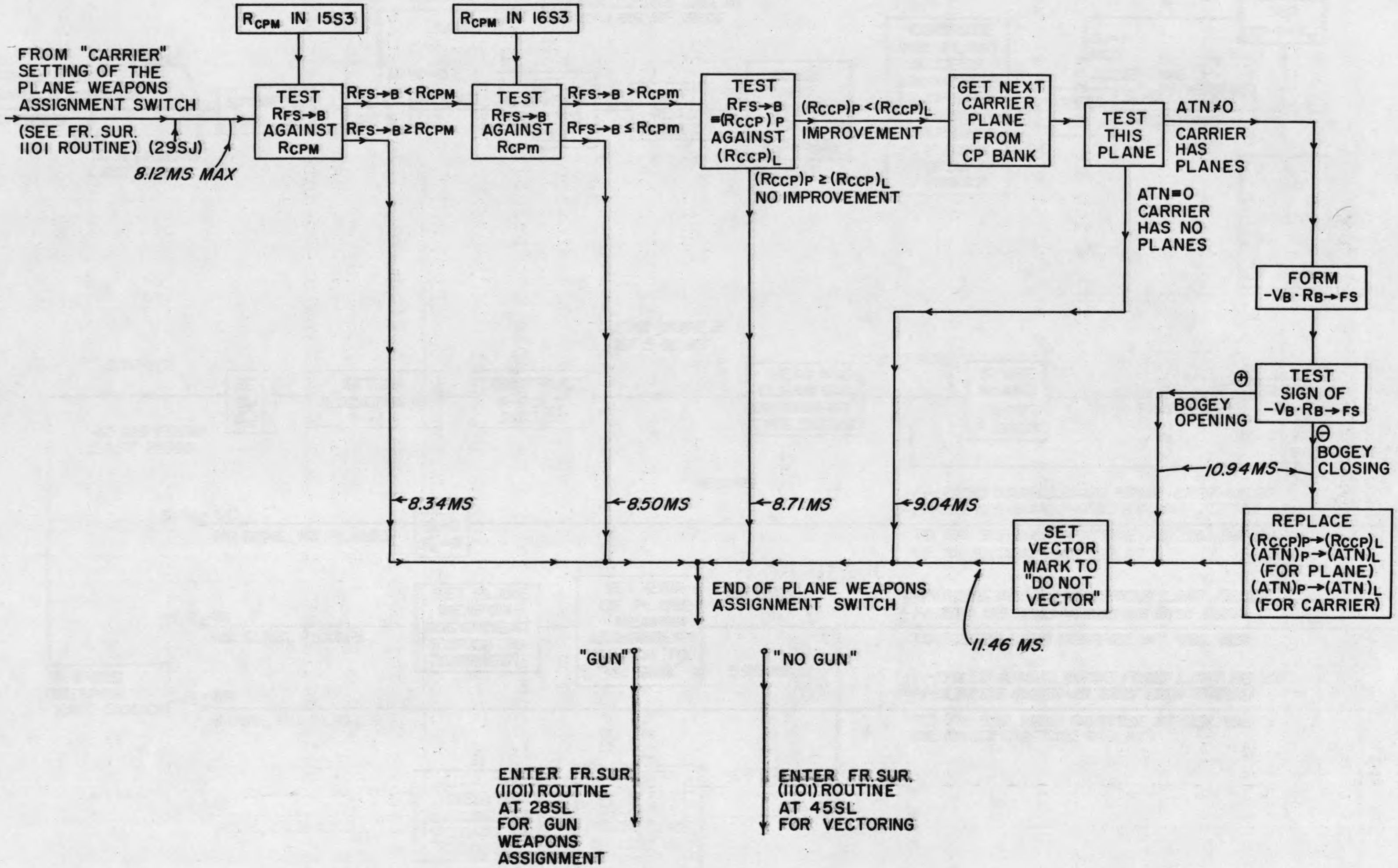

Fig 19. Carrier plane weapons assignment routines at 29SJ.

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Friend Aircraft

(1100)

This class is thoroughly discussed in sections of this report dealing with weapon assignment, vectoring, CAP and STEER; there are no additional facts or warnings which require airing here. Therefore the following is merely a terse summary of some Fac characteristics which are discussed in earlier sections.

Class 1100 refers only to airborne aircraft, which are tracked and appear on the clear picture; decked aircraft are considered as armament of their carrier.

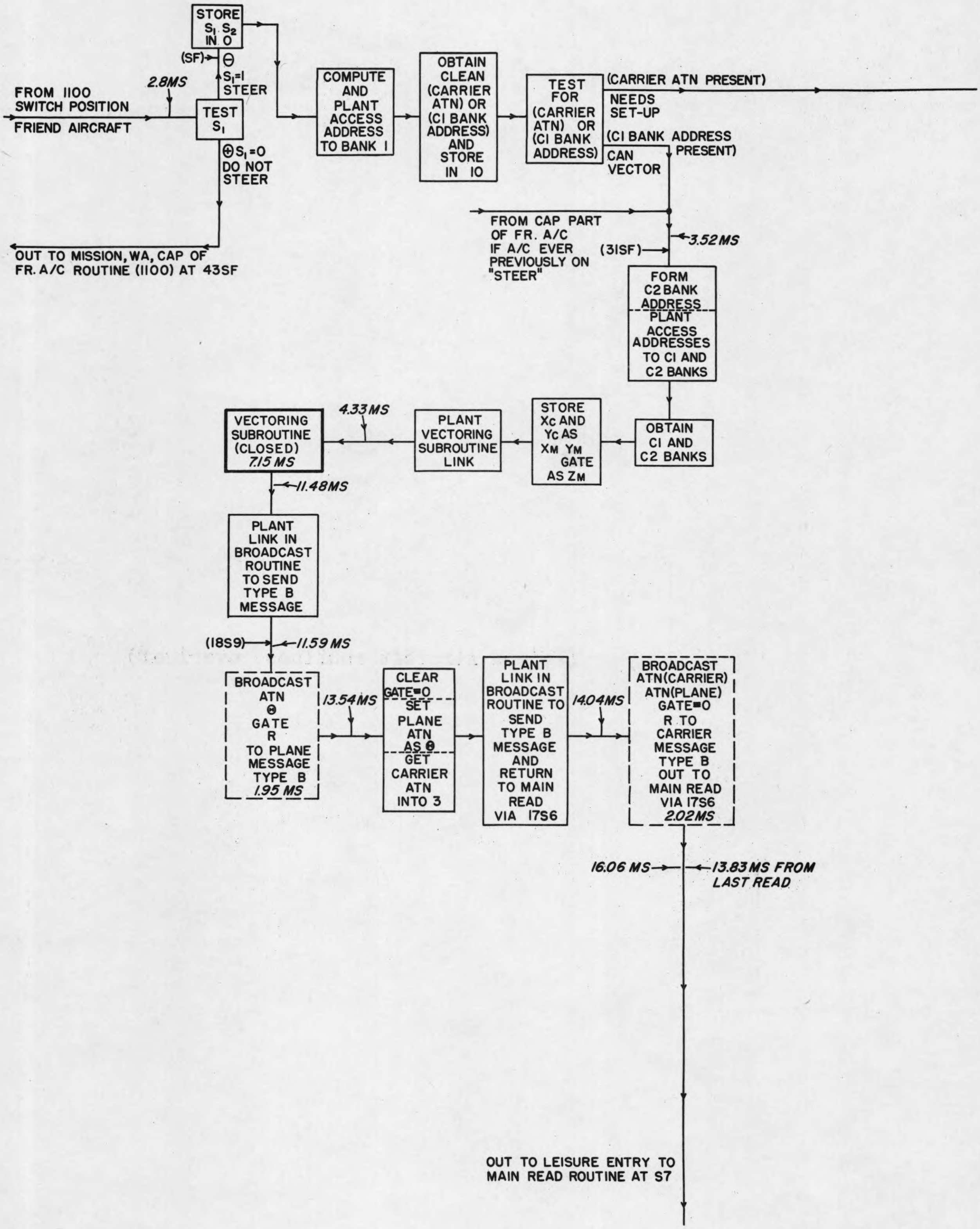
Fac are designated by clear picture digits S_1S_2 as on one of the following missions:

$$
\begin{array}{lll}
S_1S_2 = 00 & \rightleftharpoons & \text{CAP} \\
01 & \rightleftharpoons & \text{INCT} \\
10 & \rightleftharpoons & \text{STEER} \\
11 & \rightleftharpoons & \text{STEER CRITICAL}
\end{array}
$$

CAP planes are available for INTERCEPT assignment. Two kinds of CAP are recognized according to the nature of their CAP station: Carrier or georef. When assigned to INCT a georef CAP has his x_{GR} y_{GR} wiped out by the introduction into the Bank 1 word of the new mission point x_M y_M and cannot be returned to station by a simple manipulation of S_1S_2. Carrier CAP can be put through any sequence of CAP, INC, STEER or STEER CRIT. <u>except, once on STEER, it cannot go to STEER CRIT.</u>

In testing CAP for possible intercept assignment, ILLIAC checks *for* $G_{NEEDED} \leq G_{HAS}$ where $gR_{P \rightarrow B} = G_{NEEDED}$ and $S_3S_4S_5S_6 = G_{HAS}$ (in 16^{ths} of capacity). This ancillary data should be kept up-to-date by personnel.

(Friend Aircraft routines, overleaf)


STORE
S1 S2
IN O
(SF)
Θ
S1=1
STEER
2.8MS
FROM 1100
SWITCH POSITION
FRIEND AIRCRAFT
TEST
S1
⊕S1=O
DO NOT
STEER
OUT TO MISSION, WA, CAP OF
FR. A/C ROUTINE (1100) AT 43SF
COMPUTE
AND
PLANT
ACCESS
ADDRESS
TO BANK 1
OBTAIN
CLEAN
(CARRIER
ATN) OR
(C1 BANK
ADDRESS)
AND
STORE
IN 10
TEST
FOR
(CARRIER
ATN) OR
(C1 BANK
ADDRESS)
(CARRIER ATN PRESENT)
NEEDS
SET-UP
(C1 BANK ADDRESS
PRESENT)
CAN
VECTOR
FROM CAP PART
OF FR. A/C
IF A/C EVER
PREVIOUSLY ON
"STEER"
3.52MS
(31SF)
FORM
C2 BANK
ADDRESS
PLANT
ACCESS
ADDRESSES
TO C1 AND
C2 BANKS
OBTAIN
C1 AND
C2 BANKS
STORE
Xc AND
Yc AS
XM YM
GATE
AS ZM
PLANT
VECTORING
SUBROUTINE
LINK
4.33 MS
VECTORING
SUBROUTINE
(CLOSED)
7.15 MS
11.48MS
PLANT
LINK IN
BROADCAST
ROUTINE
TO SEND
TYPE B
MESSAGE
(18S9)
11.59 MS
BROADCAST
ATN
Θ
GATE
R
TO PLANE
MESSAGE
TYPE B
1.95 MS
13.54MS
CLEAR
GATE=O
SET
PLANE
ATN
AS Θ
GET
CARRIER
ATN
INTO 3
PLANT
LINK IN
BROADCAST
ROUTINE TO
SEND
TYPE B
MESSAGE
AND
RETURN
TO MAIN
READ
VIA 17S6
14.04MS
BROADCAST
ATN(CARRIER)
ATN(PLANE)
GATE=O
R TO
CARRIER
MESSAGE
TYPE B
OUT TO
MAIN READ
VIA 17S6
2.02MS
16.06 MS
13.83 MS FROM
LAST READ
OUT TO LEISURE ENTRY TO
MAIN READ ROUTINE AT S7

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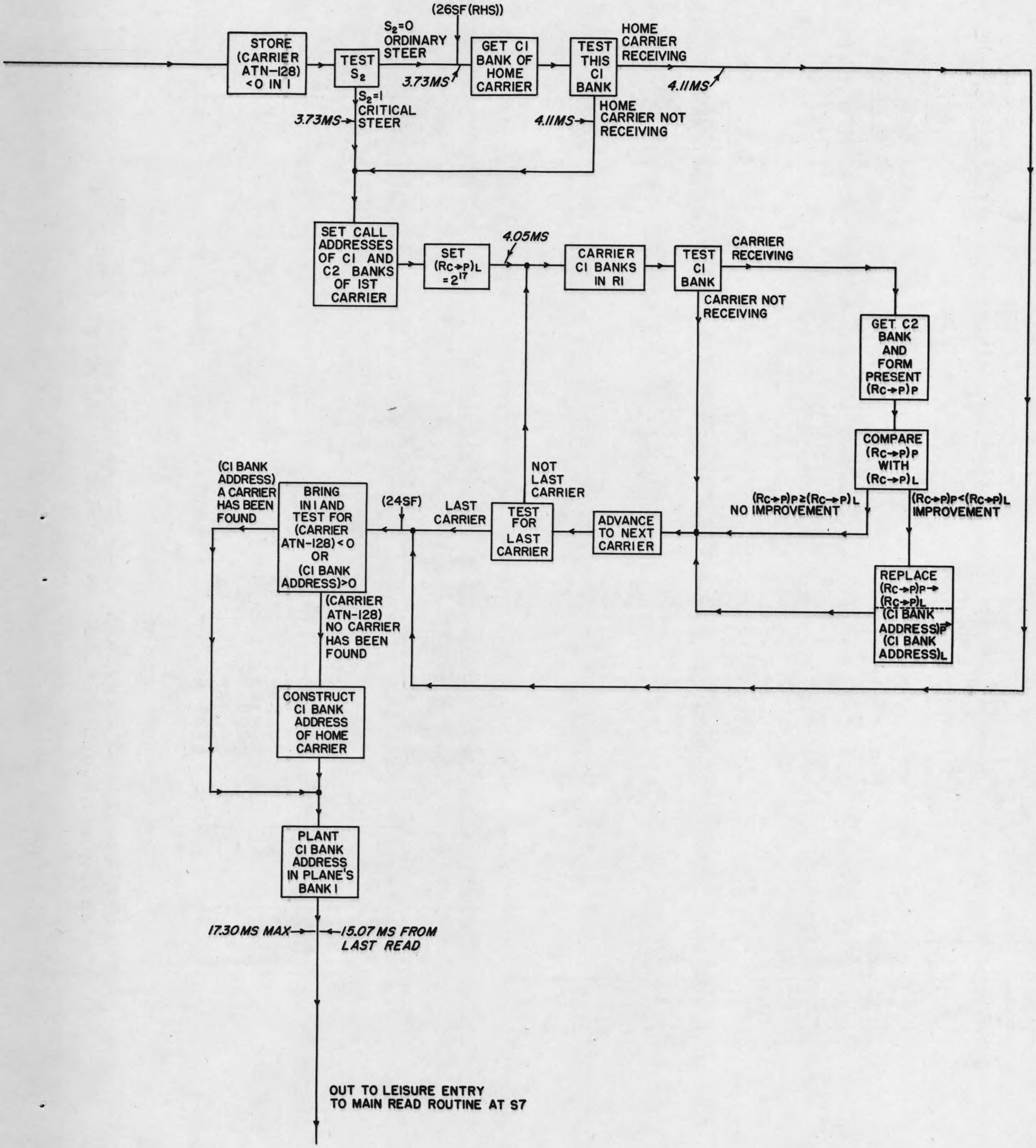

Fig 20. Friend aircraft routines (1100); steer portion at SF.

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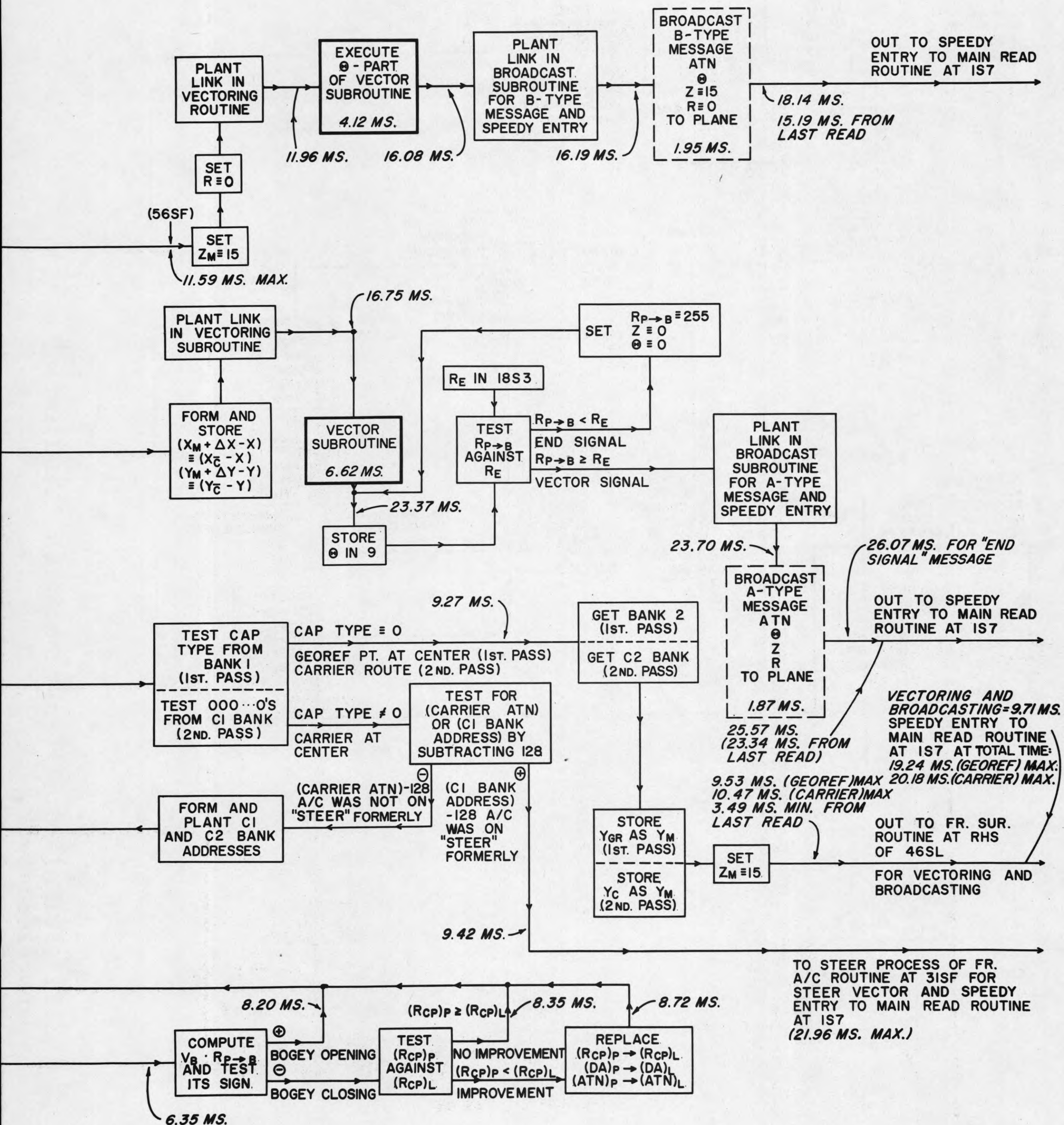

Fig 21. Friend aircraft routines (1100); Cap weapons assignment, and mission vectoring portion at 43SF.

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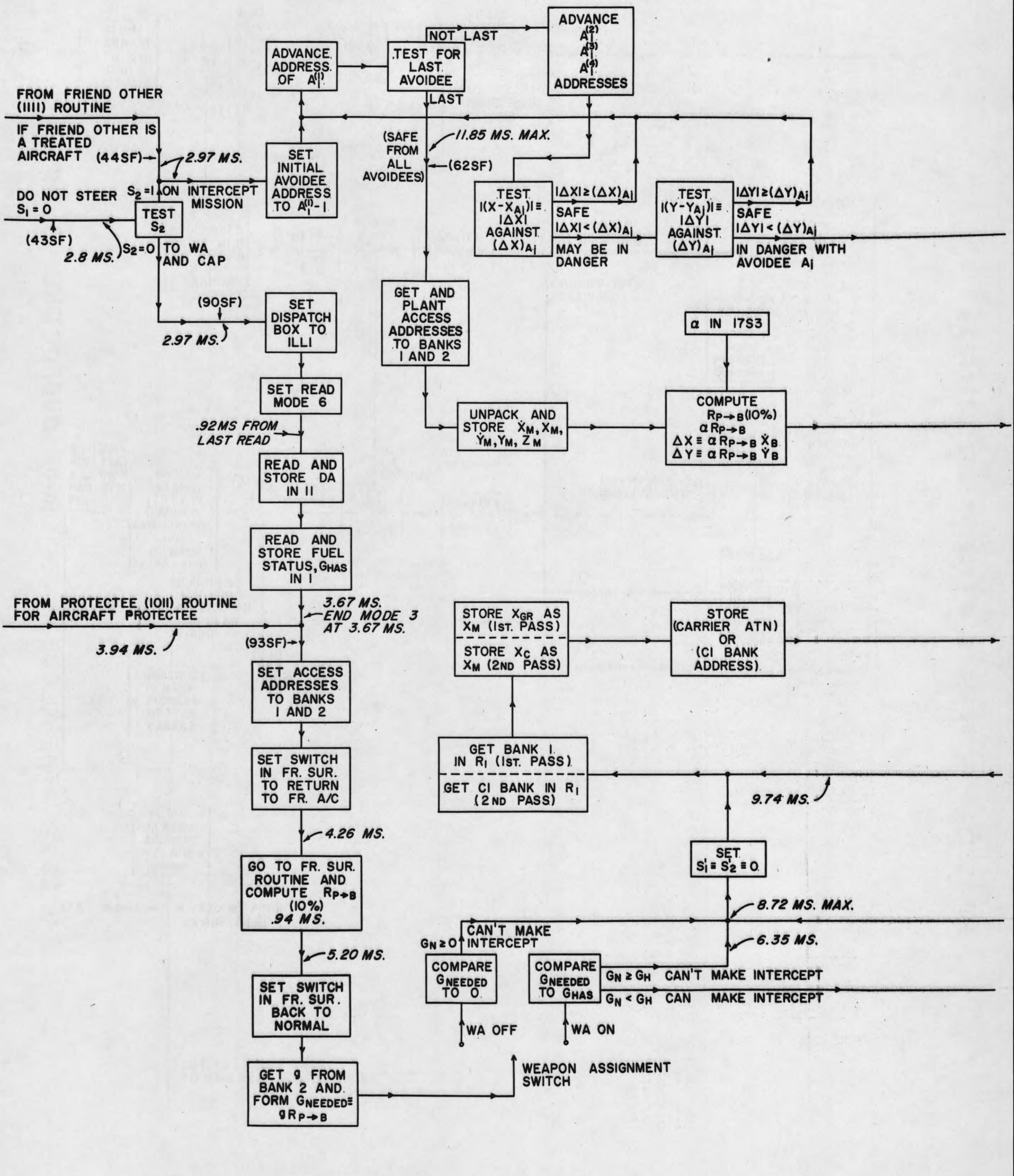


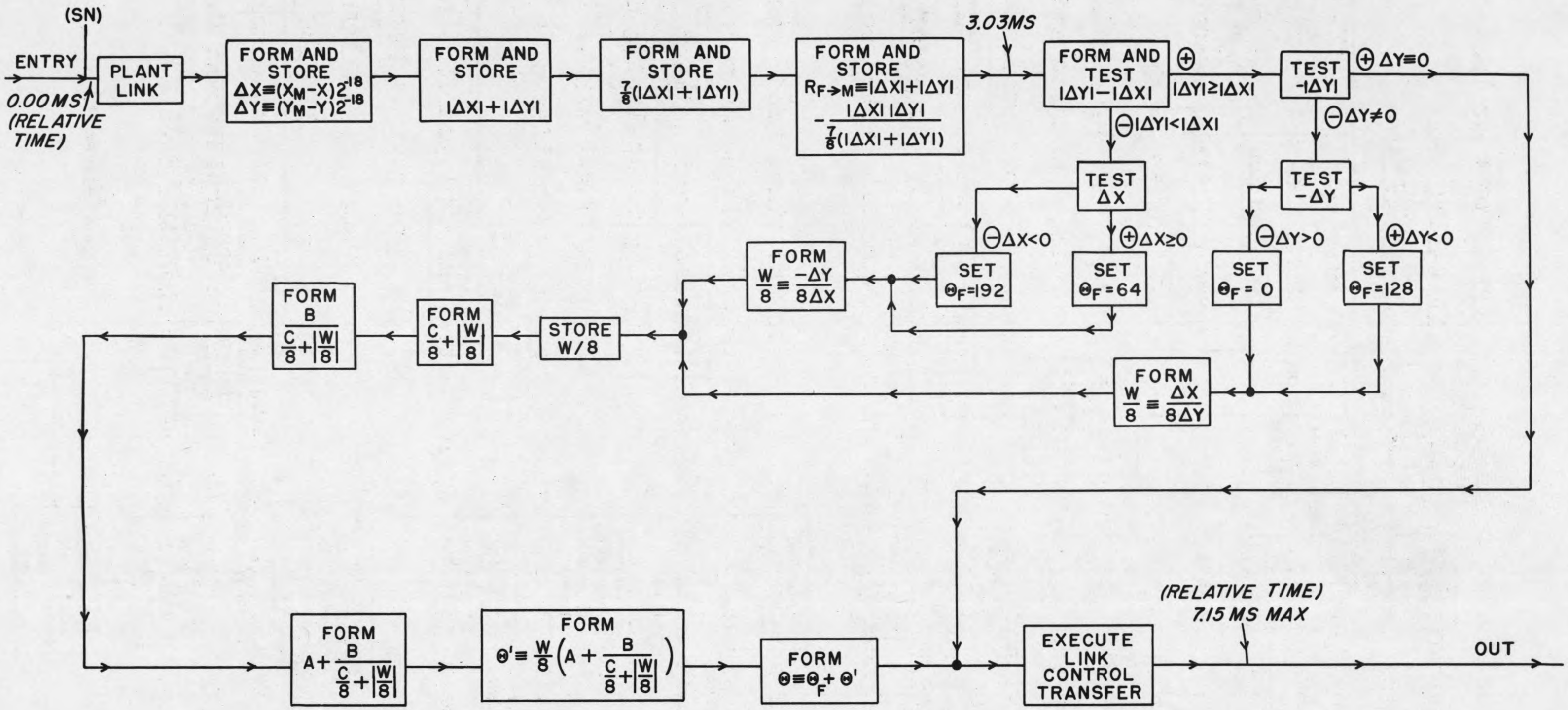


FIG. 22 THE CLOSED VECTORING SUBROUTINE AT SN

Protectee

(1011)

The class called Protectee is a group of four or less objects with respect to which bogey threats are evaluated.

If it is only the protectee characteristics which are wanted then any object, real or imaginary, can be made into a Protectee, class 1011. However, if certain other operational characteristics are desired of a Protectee, such as weapon assignment and vectoring, the object must be an actual aircraft or surface vessel. (When a carrier is also a protectee, it is carried as class CARRIER (1010) with $S_2 = 1$.)

When a Protectee is indicated as an aircraft ($S_1S_2 = 10$) it can be arranged to receive periodic vectors to reach a station and hold an orbit, either with respect to a carrier or a georef point. See pp. 281-282 of R-74. Control personnel cannot place an aircraft Protectee on STEER by manipulation of S_1S_2 but must employ a special intervention into the ILLIAC memory. Furthermore, no aircraft Protectee can receive a weapon assignment.

A surface Protectee ($S_1S_2 = 11$), on the other hand, can receive a GUN or TALOS assignment, but the ship itself is never made into a Protectee nor can control personnel indicate availability or non-availability for these assignments merely by manipulating S_1. If done at all, it must be by manipulation of the armament digits in the Bank 1 Word. Otherwise it possesses all of the properties of a normal Friend-Ship (1101).

Because the R (10 °/o) approximation is employed for calculating the threat number term $\Delta T_R = C_R (R_o - R)$, the Protectee is surrounded effectively not by an imaginary circle of radius R_o but by an imaginary octagon. If the reader will refer to Fig. 23 he will find a comparison of R (10 °/o) vs R_{EXACT}. The locus of positions around some center which appear (by 10 °/o approximation) to be equidistant from that center is not a circle but an octagon smaller than the circle.

$R_{10\%}$ vs. R

$$R_{10\%} = |\text{larger}| + \frac{|\text{smaller}|}{2}$$

$$= |x| + \frac{|y|}{2} \quad \text{or} \quad |y| + \frac{|x|}{2}$$

SO, for $R_{10\%} = 1.0$ we have

y	x
1.0	0
.9	.2
.8	.4
.7	.6
.666	.666
.6	.7
.4	.8
.2	.9
.0	1.0

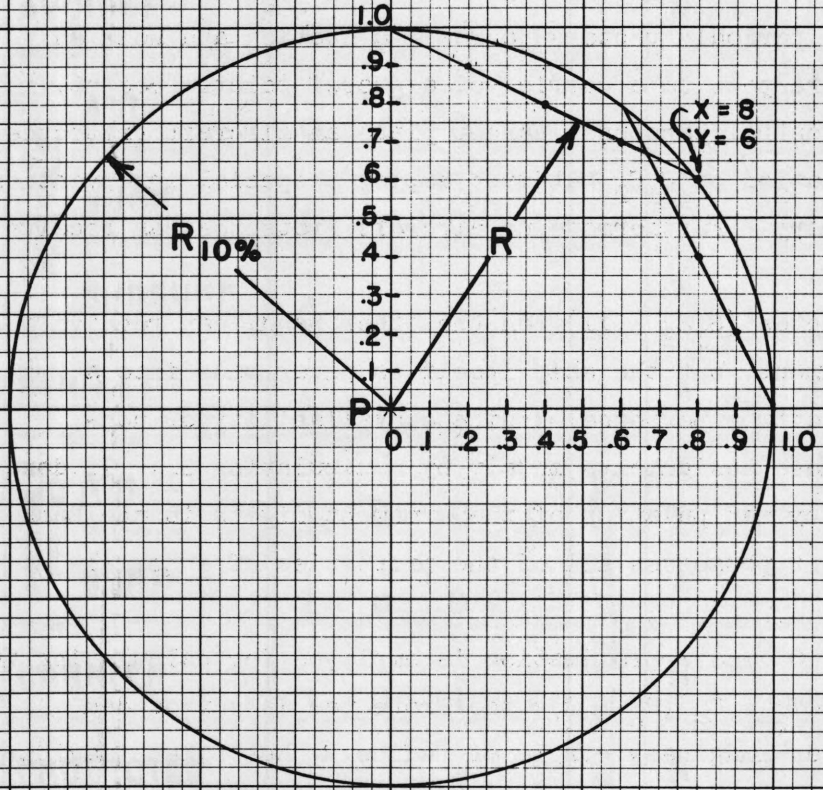


FIGURE 23.

The locus of points which appear, by 10% approximation, to be equidistant from point P is not a circle but an octagon.

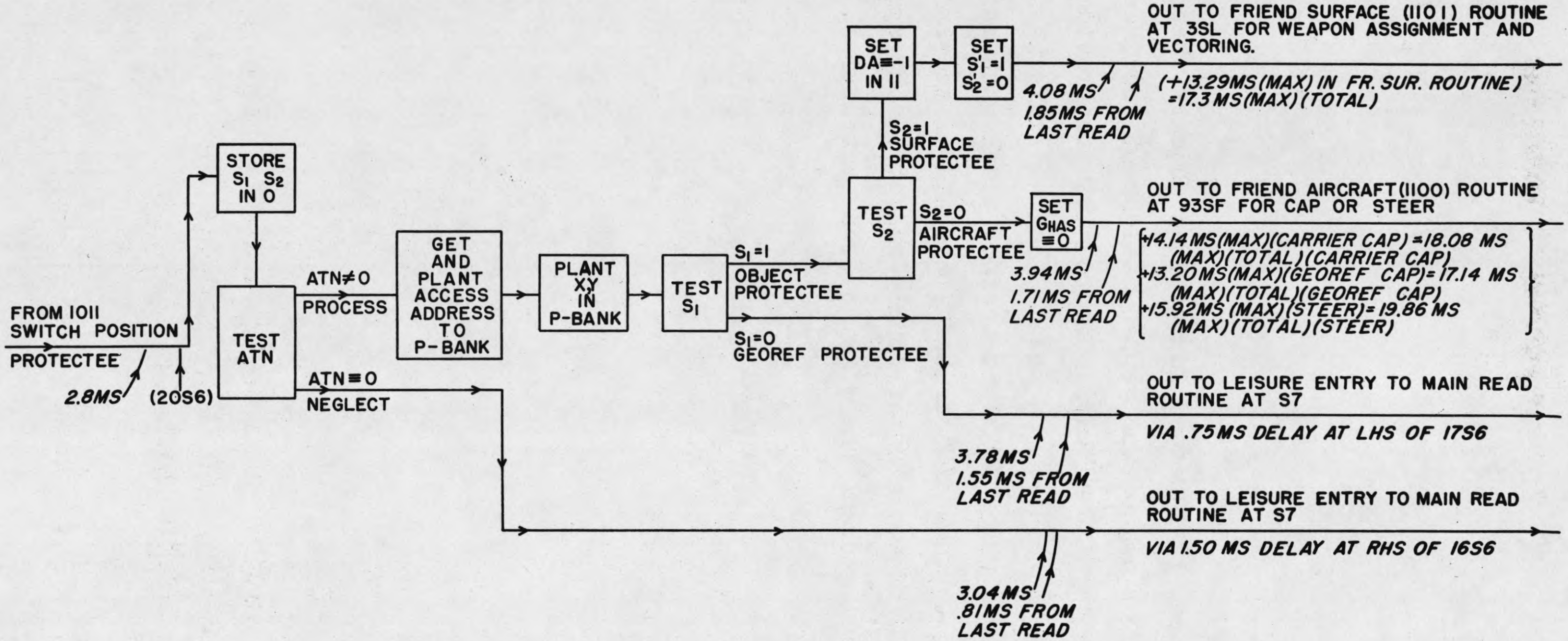
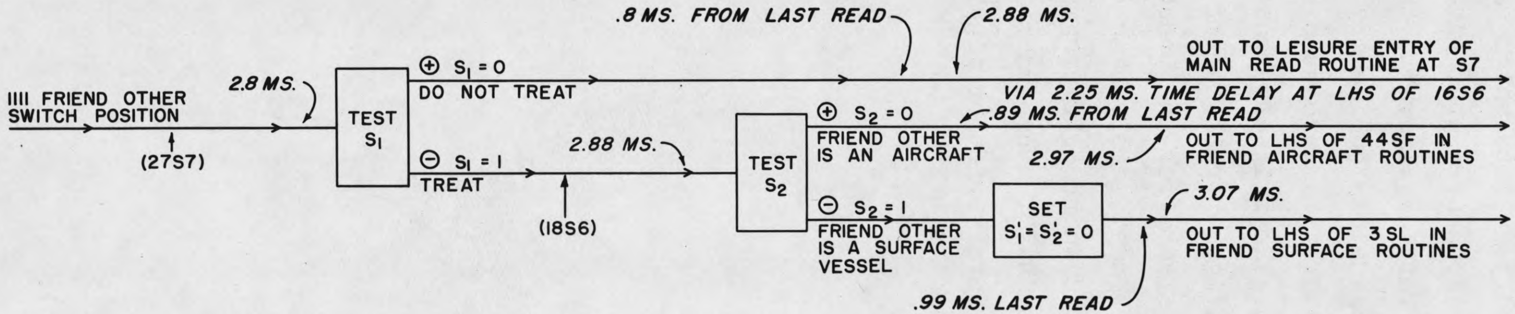


Fig 24. The protectee (1011) routines at 20S6.

Friend Other = Ignoree

(1111)

This classification is intended for tracked objects which are in no way desired to enter any of the weapon assignment routines. Generally they would be ignored by ILLIAC but it is possible to provide them with automatic vectors if the control personnel desire. This may be accomplished by inserting the Friend Other ATN into another track such as an artificial STRIKEE. Obviously, in that circumstance, the ATN of the Friend Other must not duplicate the ATN of any other friendly object in the system whereas, if it is merely to be ignored, there is no such restriction.



EXIT TO FRIEND AIRCRAFT ROUTINES FOR AVOIDANCE OF AVOIDEES AND COMPUTATION OF A CONTROL VECTOR
(MAX. ELAPSED TIME: 25.57 MS.)

EXIT TO FRIEND SURFACE ROUTINES FOR COMPUTATION OF A CONTROL VECTOR
(MAX. ELAPSED TIME: 13.90 MS.)
(MIN. ELAPSED TIME: 4.58 MS.)

Fig 25. The friend other (1111) routines at 18S6.

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Appendix I

Illiac Memory Bank Word Contents for the Various Classes

The information on tracked objects which is stored in ILLIAC includes specific characteristics of the 128 friendly objects which can be controlled. It contains such things as the object's weapon strength, pursuit range, state of readiness, present mission and, for the aircraft, the address or "name" of the home carrier. Of the approximately 300 memory locations available in ILLIAC for such storage, 256 of these are used for storing information on the missions of each of the 128 friendly, controlled objects. Each of these 128 objects has a unique Assigned Track Number (ATN) which serves not only the control personnel as a name for the track, but also as an address in ILLIAC for locating the pertinent memory bank words. Distribution of ILLIAC memory space as used in the JNS program is shown in Fig. 3 and summarized in Fig. 4 taken from R-74. The exact contents of these words are shown here in Appendix I in a series of figures taken from R-74.

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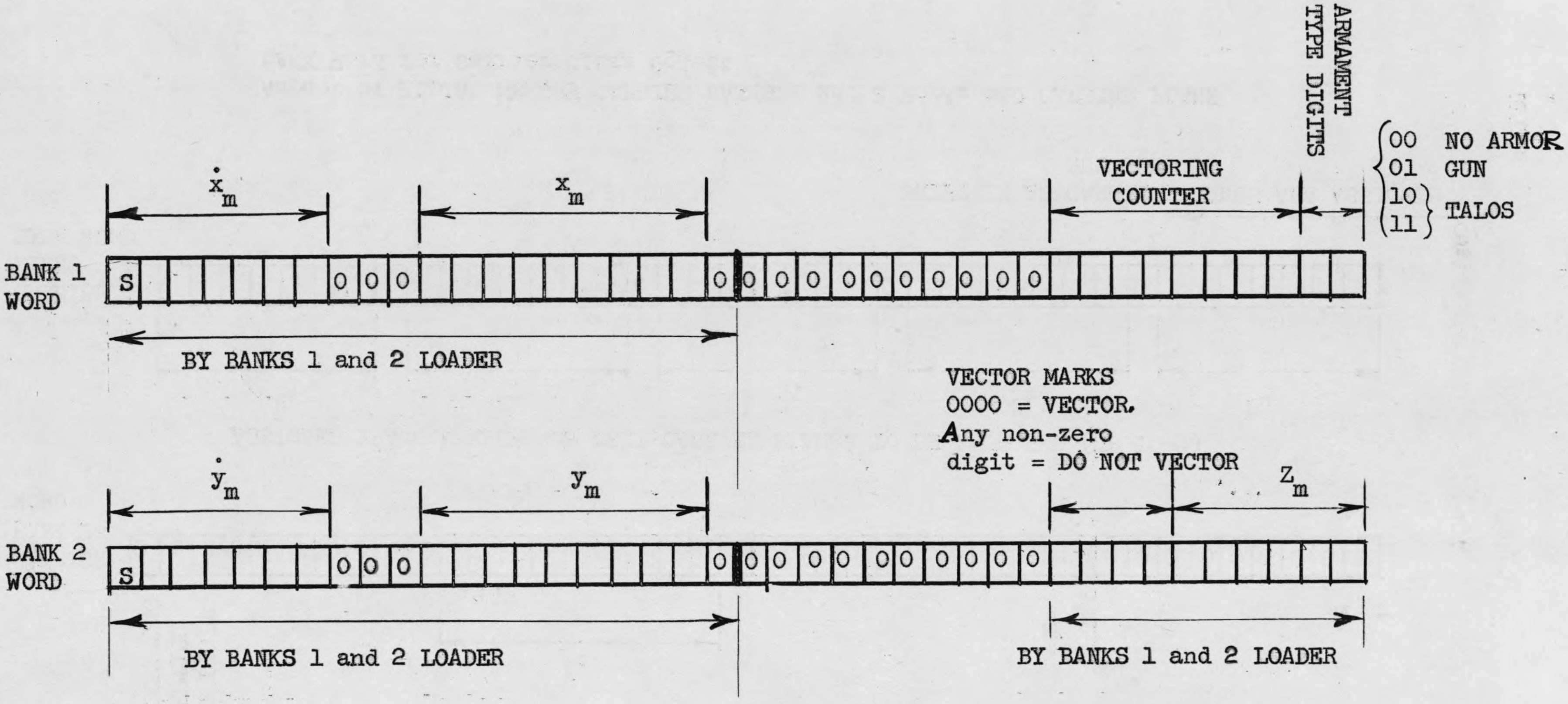

Aspect of ILLIAC MEMORY BANKS 1 and 2 Words for a Friend Surface Class Object.

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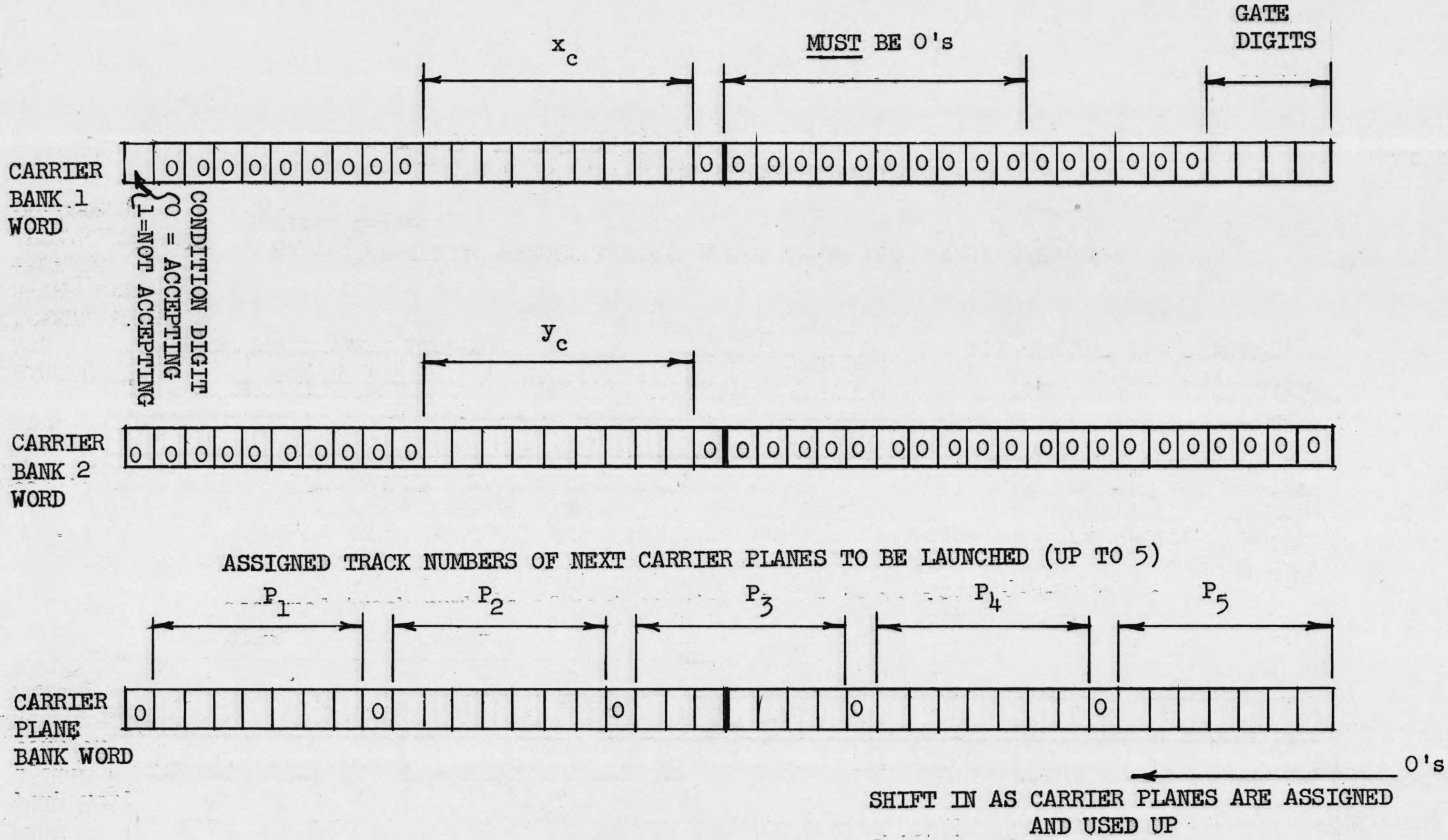

Aspect of ILLIAC MEMORY CARRIER BANKS 1 and 2 Words and CARRIER PLANE BANK Word for Carrier Class Object

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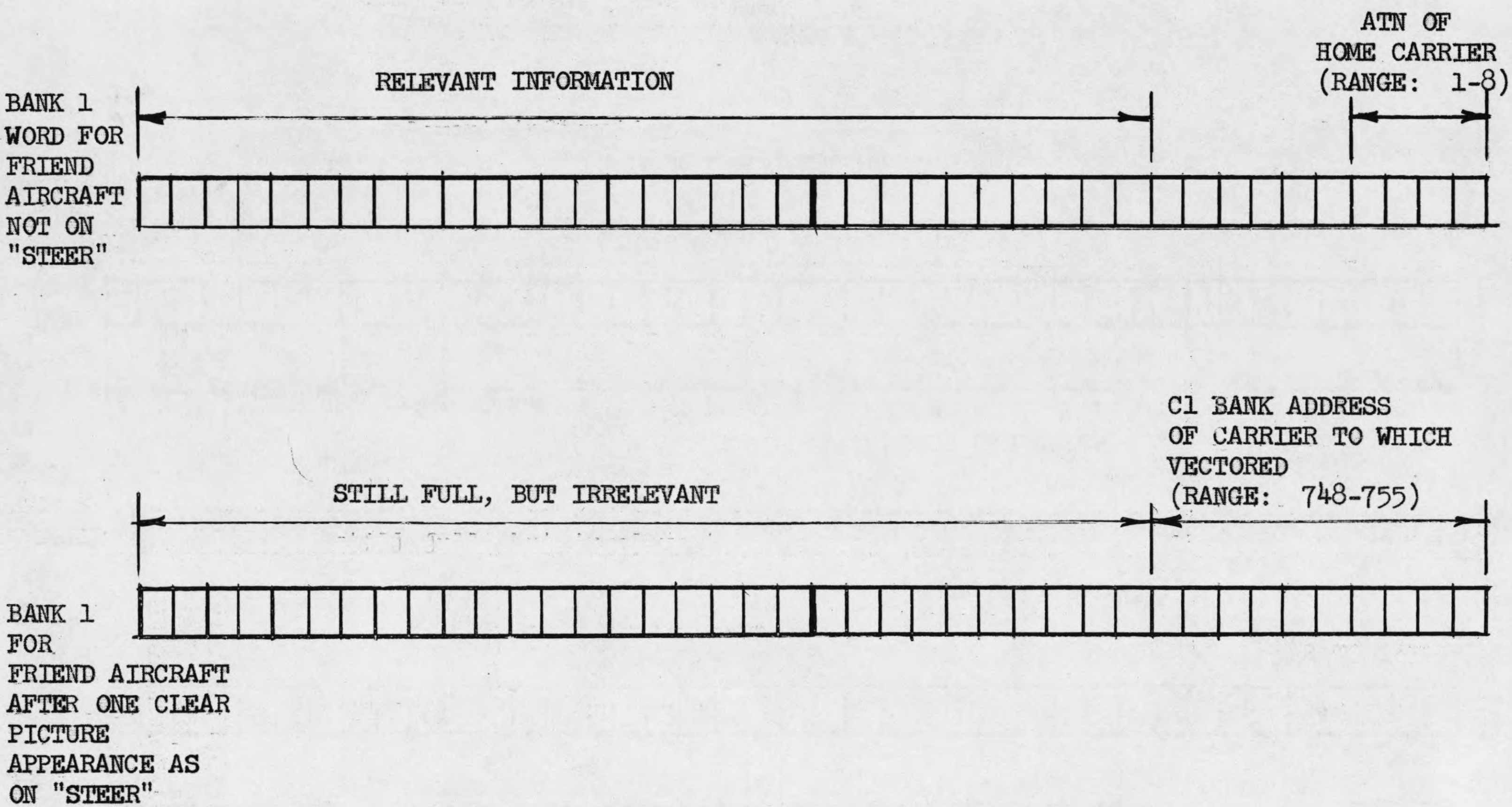

Significance of the ILLIAC Bank 1 Word for Friend Aircraft Steer Procedure.

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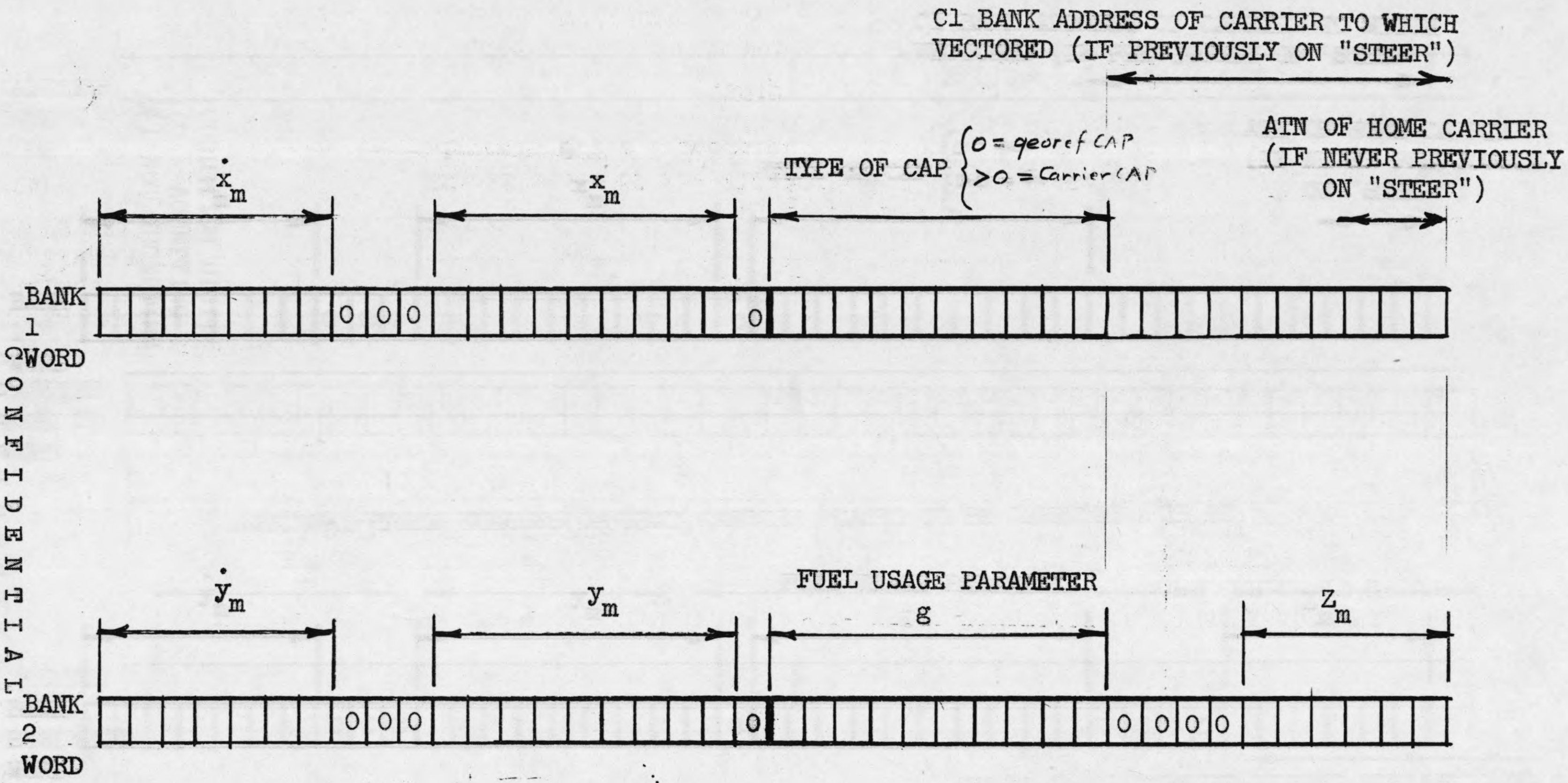

Significance of ILLIAC Bank 1 and 2 Words for Friend Aircraft Intercept Vectoring Procedure.

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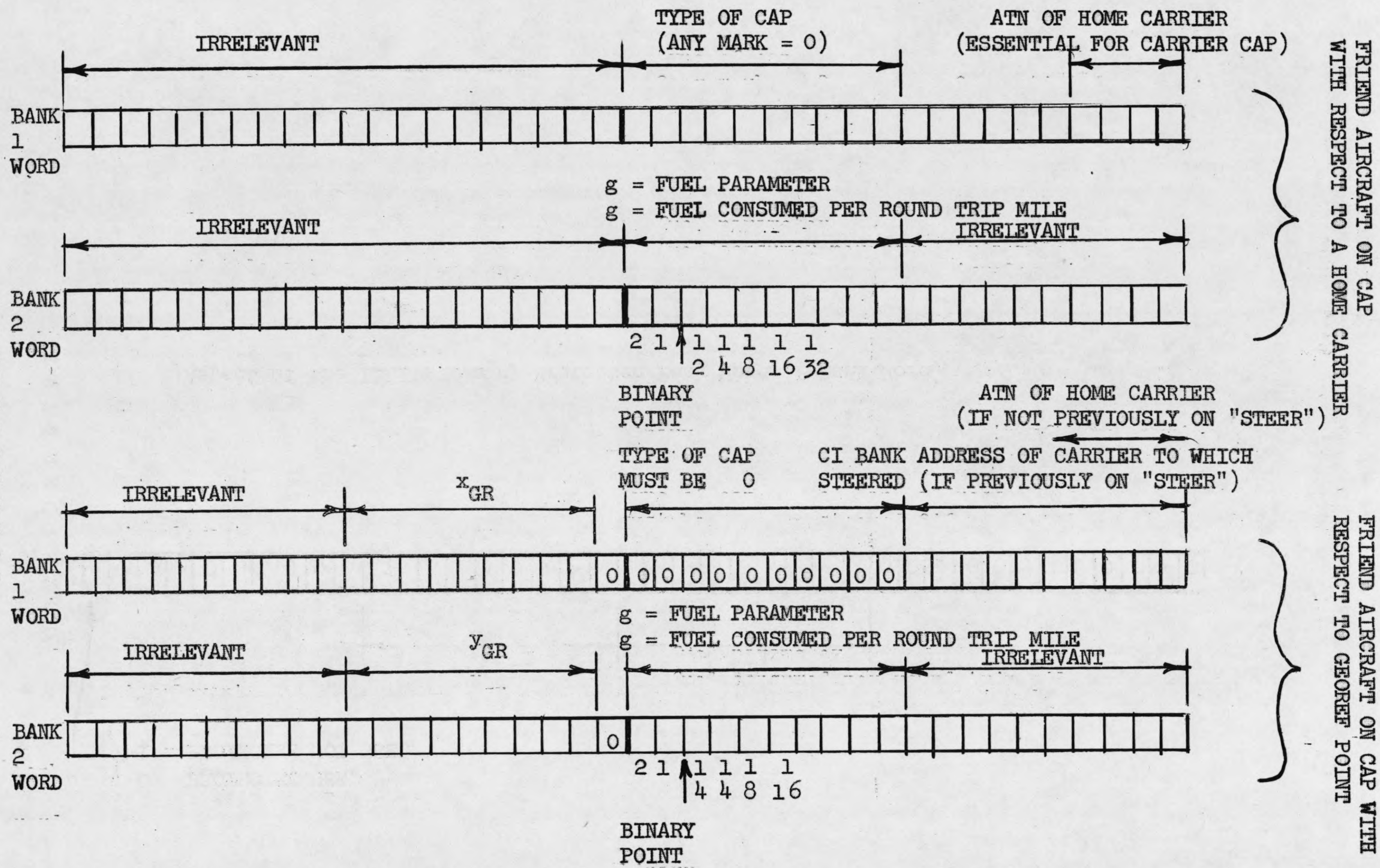

Significance of ILLIAC Bank 1 and 2 Words for Friend Aircraft CAP and Weapons Assignment Procedures.

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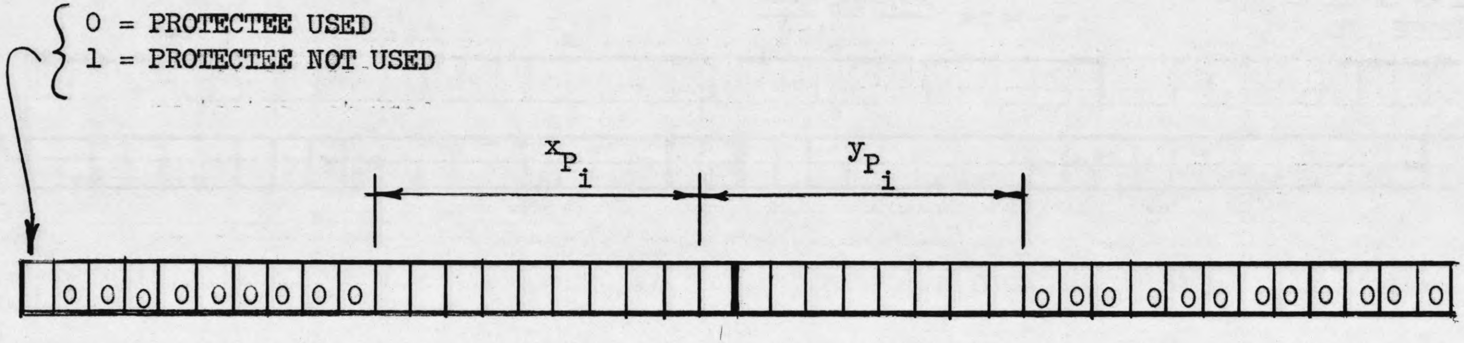

Aspect of the ILLIAC Memory Protectee Bank Word (P-Bank Word)

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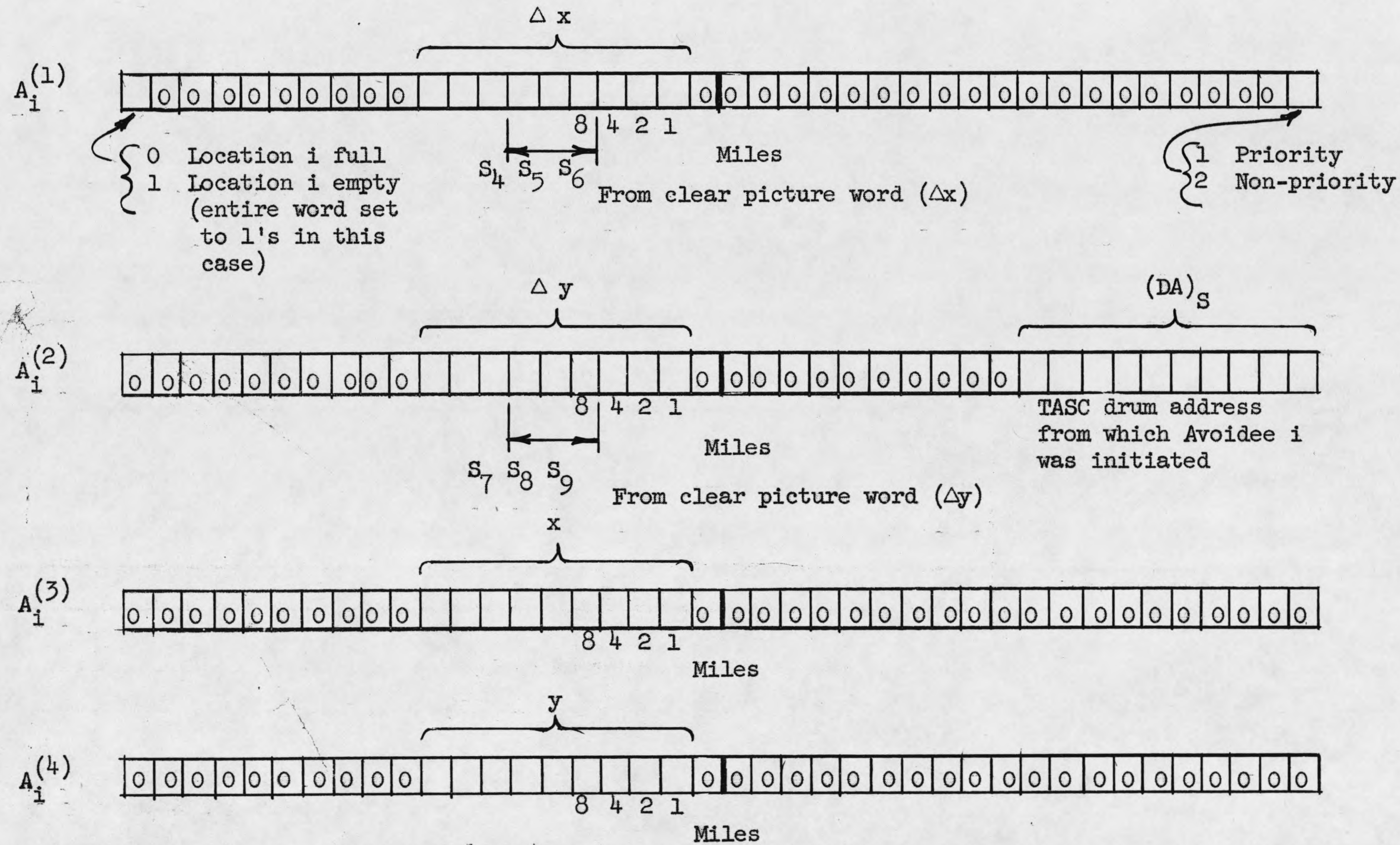

Aspect of the ILLIAC Memory Avoidee Bank Words

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Appendix II

Weapon Assignment Priorities

Each of the control parameters α_i may be set independently by the control personnel and can be chosen in such a way as to establish priorities among the four weapon types.

If it is desired, the priority may be made absolute so that, regardless of range, a certain weapon type, if available, will always be chosen over any other. As an example, it may be arranged that, when available, a CAP will always be assigned before a carrier plane, a carrier plane before a TALOS, a TALOS before a gun. Such an absolute priority scale is possible because of the very wide range in available α's as compared to the relatively narrow range of possible R_c's. Any α_i may be chosen between $\pm 2^{-1}$ and $\pm 2^{-21}$ while any R_{ci} must lie in the range 1 mile $\leqq R_c \leqq$ 511 miles and is carried as a scaled number in ILLIAC as $2^{-18} \leqq R_c^1 \leqq 2^{-9}$.

In R-74, JNS suggests the use of

$$\alpha_p = -2^{-10} \quad \text{(CAP)}$$

$$\alpha_{cp} = -2^{-21} \quad \text{(Carrier Planes)}$$

$$\alpha_t = 2^{-21} \quad \text{(TALOS)}$$

$$\alpha_g = 2^{-10} \quad \text{("GUNS")}$$

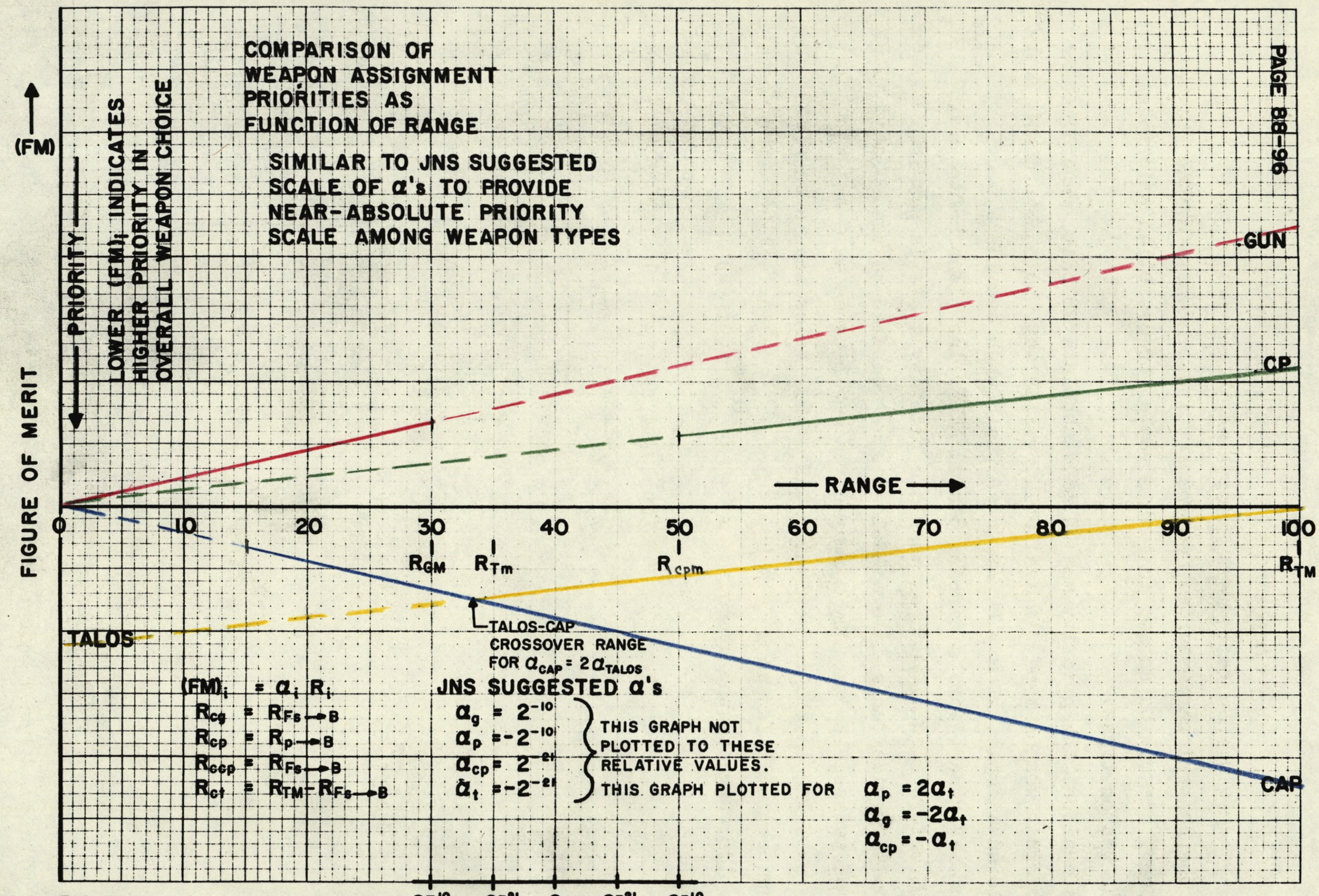
which will give

$$-2^{-19} \leqq (FM)_p \leqq -2^{-28}$$

$$-2^{-30} \leqq (FM)_{cp} \leqq -2^{-39}$$

$$2^{-39} \leqq (FM)_t \leqq 2^{-30}$$

$$2^{-28} \leqq (FM)_g \leqq 2^{-19}$$



COMPARISON OF WEAPON ASSIGNMENT PRIORITIES AS FUNCTION OF RANGE
SIMILAR TO JNS SUGGESTED SCALE OF α's TO PROVIDE NEAR-ABSOLUTE PRIORITY SCALE AMONG WEAPON TYPES
PAGE 88-96
(FM)
FIGURE OF MERIT
PRIORITY
LOWER $(FM)_i$ INDICATES HIGHER PRIORITY IN OVERALL WEAPON CHOICE
GUN
CP
TALOS
CAP
RANGE
0
10
20
30
40
50
60
70
80
90
100
R_{GM}
R_{Tm}
R_{cpm}
R_{TM}
TALOS-CAP CROSSOVER RANGE FOR $\alpha_{CAP} = 2\alpha_{TALOS}$
$(FM)_i = \alpha_i R_i$
$R_{cg} = R_{Fs \to B}$
$R_{cp} = R_{p \to B}$
$R_{ccp} = R_{Fs \to B}$
$R_{ct} = R_{TM} - R_{Fs \to B}$
JNS SUGGESTED α's
$\alpha_g = 2^{-10}$
$\alpha_p = -2^{-10}$
$\alpha_{cp} = 2^{-21}$
$\alpha_t = -2^{-21}$
THIS GRAPH NOT PLOTTED TO THESE RELATIVE VALUES.
THIS GRAPH PLOTTED FOR
$\alpha_p = 2\alpha_t$
$\alpha_g = -2\alpha_t$
$\alpha_{cp} = -\alpha_t$
-2^{-10}
-2^{-21}
0
2^{-21}
2^{-10}

FIG. II A

Now while certainly permissible, it is not necessary to employ such widely differing α's, even to achieve an effective absolute priority. It will be instructive to plot $(FM)_i$ vs. Range for the four different weapon types, for inspection of these graphs provides a ready insight to the possibilities and limitations inherent in this method of assigning weapons. Figure II A is such a plot and resembles the result would would be obtained using Snyder values for α_i except that the value scale has been drastically narrowed and an absolute priority scale is not quite achieved.

In this graph, "GUNS" are considered to be conventional AA guns as well as missiles such as tartar and highly advanced terrier types which are given a maximum assignment range of 30 miles. Carrier planes on deck have been arbitrarily allowed a minimum range of 50 miles because the time required to climb to combat altitude severely limits their close-in usefulness. In the JNS program no special provision exists for gaining altitude during an interception. The vectoring routines direct the interception toward a pseudo-collision point as if there were no altitude separation to be closed; the interceptor is directed on a nearly straight course in the case of nearly head-on interceptions. Since bogey altitude is not considered at time of weapon assignment, the minimum assignment range should be more like 100 miles for carrier planes.* Talos and CAP in turn have minimum assignment ranges; TALOS, because of the time required for fire control lock-on and computations, launching manipulations, and initial flight control; CAP because of time required to turn toward the bogey. Now the R_c's are, for all weapons except TALOS, merely the present range from the weapon to the bogey, causing the $(FM)_i$ to be a linear function of range, a function whose value is zero when range is zero. Talos' R_c is also a linear function but it drops to zero at maximum range. Because of the existence of minimum ranges below which some R_c's are not defined, the (FM) plots for TALOS and CAP, for example, appear as dashed lines for all ranges less than 35 and 15 miles respectively. The particular values we have chosen for the minimum

---

* If rate of climb is 5000 ft/min. and speed is 300 knots during climb, while bogey velocity is 600 knots, 45 miles would be closed between deck launched interceptor and bogey before interceptor reached 15,000 feet flying a straight course; 120 miles for 40,000 feet. At any rate, no matter what course the interception takes to reach 40,000 feet, the bogey will advance 80 miles during this time.

ranges may not be operationally correct. For the discussion in hand that is of no importance just so long as they exist.

Examination of the graph yields some interesting facts. An absolute priority scale has nearly been established even with a very small range of α_i. From 0-15 miles only Guns can accept an assignment. From 15 miles out to 70 miles there is a possibility of assigning either CAP or TALOS, the CAP (FM)'s in the range 15-35 miles being equal to certain TALOS (FM)'s in the range 35-72 miles. If the TALOS ship is more than 72 miles from the bogey, CAP will always receive the assignment regardless of its own distance to the bogey provided it lies within the permitted limits. If CAP is not available, TALOS will surely receive the assignment, since its whole curve lies lower than any portion of those of the other two weapons.

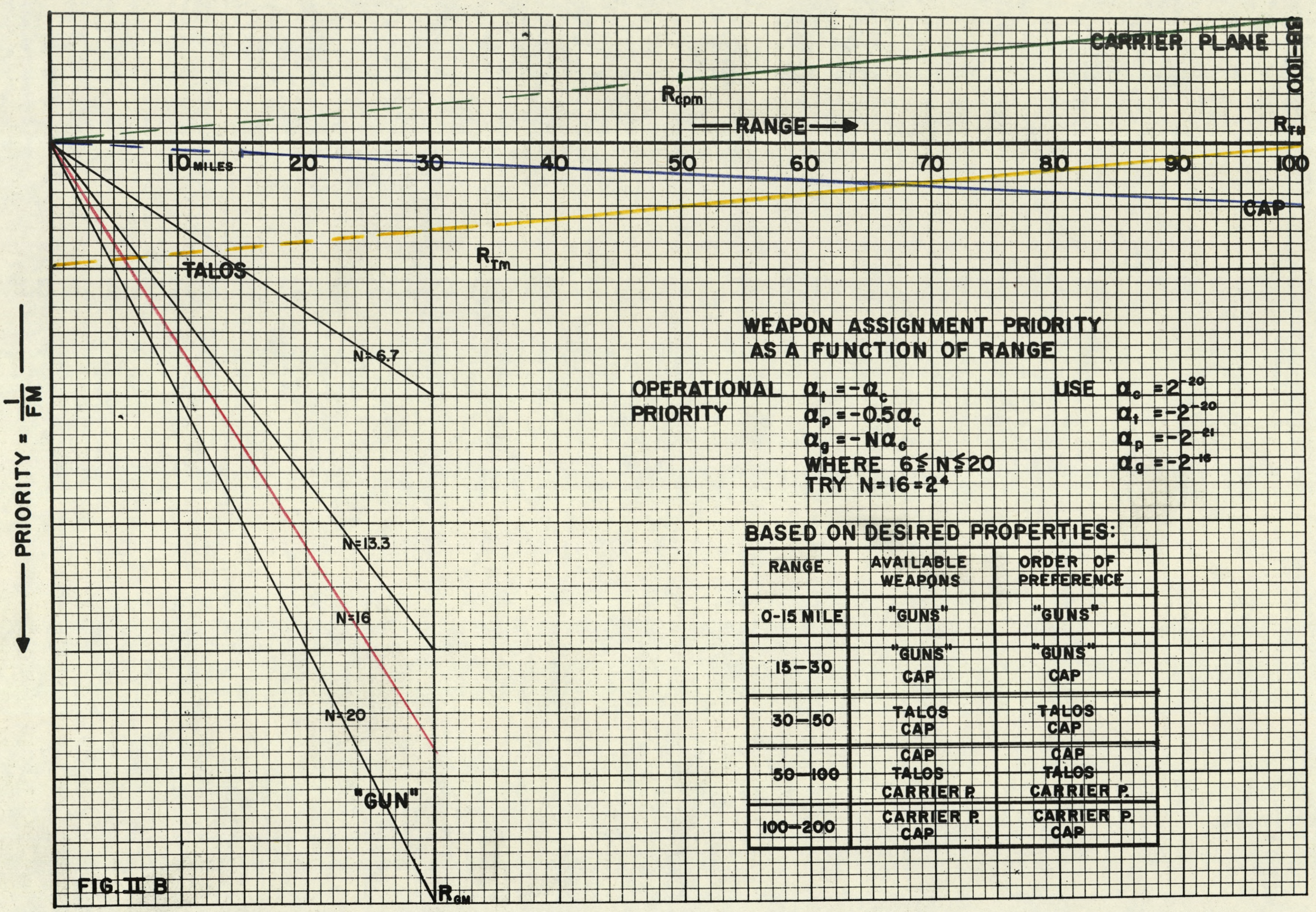
By making use of the maximum and minimum assignment ranges for the different weapon types, and the possibility for positive or negative slopes, one can easily adjust the (FM) graphs to give several kinds of priority scales, some of which are functions of range, and others which are absolute. It is apparent that the latter type may be achieved even with α's which are in the ratio of small numbers. An illustration of this is provided by the graph of Figure II A if the following slight changes are made: 1. Change TALOS curve to intersect that of CAP at 15 instead of 34 miles. 2. Lower the slope of the Gun curve until at range R_{GM} the value of $(FM)_g$ is just lower than the value of $(FM)_c$ at minimum carrier range. The resulting α's, giving absolute priority of CAP over TALOS, TALOS over CARRIER PLANES, CARRIER PLANES over GUNS, would become

$$\alpha_p = -2\alpha_{cp}$$

$$\alpha_t = -.35\alpha_{cp}$$

$$\alpha_g = +1.5\alpha_{cp}$$

An alternative arrangement which appears a little more attractive than the one just proposed is illustrated in Figure II B and is based on the following assumptions, considerations, and preferences.



RANGE	AVAILABLE WEAPONS	ORDER OF PREFERENCE
0-15 MILE	"GUNS"	"GUNS"
15—30	"GUNS" CAP	"GUNS" CAP
30—50	TALOS CAP	TALOS CAP
50—100	CAP TALOS CARRIER P.	CAP TALOS CARRIER P.
100—200	CARRIER P. CAP	CARRIER P. CAP

FIG. II B

1. From 0-15 miles no weapons other than "GUNS" are available.

2. For 15-30 miles ranges both "GUNS" and CAP may be considered effective, with the former preferred because of the need for maximum speed and ability to close an altitude differential in a matter of seconds.

3. For 30-50 mile ranges both TALOS and CAP are possible choices, with TALOS preferred; CAP may not be able to turn or climb fast enough to close this short range.

4. For 50-100 mile ranges, CAP, TALOS, and CARRIER (decked) planes are all possible choices, listed in order of probable preference. A manned interceptor, given sufficient running time to reach combat altitude, and benefiting from both surface-based tracking radar and A.I. lock-on radar may be more effective than a long range missile. Either of these appear to have an advantage over a decked aircraft up to 100 miles.

5. From 100 miles to maximum intercept range, the deck-launched plane has sufficient time to climb to even high altitude, and has a greater range potential than a CAP who has already expended some fuel on patrol.

The choice of α's employed in constructing Figure II B provide for the considerations listed above. Such a choice has the following specific characteristics.

a. If there is any "GUN" between about 4* and 30 miles from the bogey, the assignment will always go to the "GUN". If there is no GUN in this range, but there is one closer (0-4 miles) the assignment may go to either the GUN or to a distant TALOS or CAP.

b. If the bogey lies within 35 to 50 miles of a TALOS ship, TALOS will be assigned before any available CAP regardless of the CAP's distance to the bogey. If no TALOS ship lies closer than 50 miles to the bogey the assignment may go to either CAP or TALOS if both are within striking range. A 50-mile CAP is considered equivalent to a 100-mile TALOS, a 60-mile CAP to an 80-mile TALOS, a 68-mile CAP to a 68-mile TALOS. Range for range, the CAP has the preference between 50 and 68 miles, the TALOS between 68 and 100 miles.

---

* This "4" may be readily changed to some preferred value by changing the slope of the "GUN" curve. If $\alpha_g = -N\alpha_c$, N can be anything greater than 6.7 without disturbing the priorities. The lower the N, the greater the minimum "GUN" range for absolute priority. If N = 6.7, this minimum increases to about 10 miles.

c. Beyond 100 miles, CAP has absolute priority up to its maximum range (which might be set at about 120-150) after which carrier planes assume absolute priority.

Appendix III
The Control Parameters

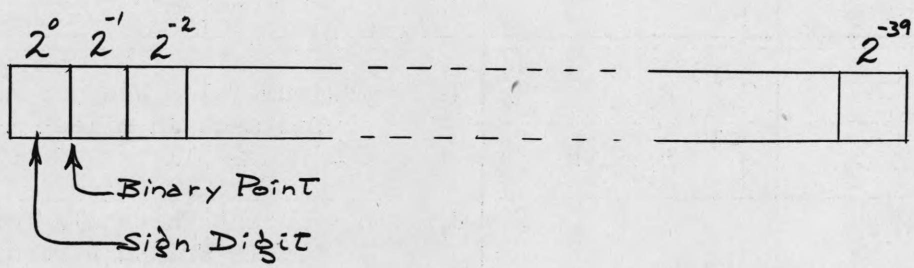
Various constants such as interceptor fuel consumption per round-trip mile, maximum missile range, weighting constants for weapon assignment priority scaling, and many (21) others must be chosen by control personnel and stored in ILLIAC for computer use in the control program routines. A reasonable set of values for these constants is shown below.

Control Parameter	Assigned Value	Control Parameter	Assigned Value
R_o	100 miles	α_t	-2^{-20}
T_{0000th}	100	α_g	-2^{-16}
R_{GM}	60,000 yds	$(\Delta x)_t$	8
T_{0100th}	100	$(\Delta y)_t$	8
R_{TM}	90 miles	$(\Delta)_G$	8
T_{1000th}	100	k	64
R_{Tm}	30 miles	Z_G	60,000 feet
$(\Delta T)_s$	1	R_G	40,000 yds
C_R	2^{-5}	R_{CPM}	200 miles
C_V	1	R_{CPm}	50 miles
α_p	-2^{-21}	α (Vectoring)	0.00150
α_c	2^{-2}	R_E	8 miles

Appendix III cont'd

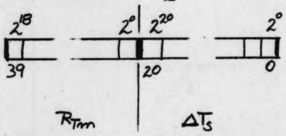
On the next two pages is a table showing the storage locations in ILLIAC and the form of insertion for the 24 control parameters. Many of them are inserted as scaled numbers in order to get two of them into a single ILLIAC 40-digit word, and the scaling factor, if present, is shown as a multiplier for the control parameter in the column labeled "Form of Word". A scaling factor of 2^{-n} has the effect of shifting the binary point to right of the 2^{-n} digit of the normal ILLIAC word.

Normal ILLIAC Word



Appendix III

The Control Parameters as Stored in the Control Parameter Bank at S3

Location of Word In ILLIAC Memory (Using S3) (Decimal) (Sexadecimal)	Form of Word	Definitions and Restrictions
0S3 (41) (029)	$2^{-18}\ R_o\ +$ $2^{-39}\ T_{0000}th$	R_0 = Threat Radius in miles $0 \leq R_0 \leq 511$ $T_{0000}th$ = Threat Threshold for Unidentified Aircraft $0 \leq T_{0000}th \leq 127$
1S3 (42) (02K)	$2^{-18}\ R_{GM}\ +$ $2^{-39}\ T_{0100}th$	R_{GM} = Maximum Gun Weapons Assignment Distance in miles $0 \leq R_{GM} \leq 511$ $T_{0100}th$ = Threat Threshold for Foe Aircraft $0 \leq T_{0100}th \leq 127$
2S3 (43) (02S)	$2^{-18}\ R_{TM}\ +$ $2^{-39}\ T_{1000}th$	R_{TM} = Maximum Talos Weapons Assignment Distance in miles $0 \leq R_{TM} \leq 511$ $T_{1000}th$ = Threat Threshold for Probable Friend Aircraft $0 \leq T_{1000}th \leq 127$
3S3 (44) (02N)	$2^{-18}\ R_{Tm}\ +$ $2^{-39}\ (\Delta T)_S$ 	R_{Tm} = Minimum Talos Weapons Assignment Distance in miles $0 \leq R_{Tm} \leq 511$ $(\Delta T)_S$ = Threat Increment for Size $0 \leq (\Delta T)_S \leq \left(2^{20} + 2^{19} \ldots . 2^{0}\right)$
4S3 (45) (02J)	$\underbrace{2^{-21}}\ C_R$	C_R = Threat/mile inside threat Radius R_0 $0 \leq C_R \leq \left(2^{21} + 2^{20} + \ldots 2^{0} + 2^{-1} \ldots 2^{-18}\right)$

Scaling factor. Multiply absolute value by scaling factor for insertion into ILLIAC.

5S3 (46) (02F)	$2^{-39}\ C_V$	C_V = Threat/ $\frac{\text{mile}}{1.5\ \text{sec}}$ of closing velocity $0 \leq C_V \leq \left(2^{39} + 2^{38} \ldots\ldots. 2^0\right)$
6S3 (47) (02L)	α_P	α_P = Weapons Assignment Weighting Factor for Airborne Planes $2^{-21} \leq \lvert\alpha_P\rvert \leq 2^{-1}$
7S3 (48) (030)	α_C	α_C = Weapons Assignment Weighting Factor for Aircraft on Carrier Decks $2^{-21} \leq \lvert\alpha_C\rvert \leq 2^{-1}$
8S3 (031)	α_T	α_T = Weapons Assignment Weighting Factor for Talos Ships $2^{-21} \leq \lvert\alpha_T\rvert \leq 2^{-1}$
9S3 (50) (032)	α_G	α_G = Weapons Assignment Weighting Factor for Gun Platforms $2^{-21} \leq \lvert\alpha_G\rvert \leq 2^{-1}$
10S3 (033)	$2^{-38}\ (\Delta x)_T +$ $2^{-41}\ (\Delta y)_T$	$(\Delta x)_T$, $(\Delta y)_T$ = Standard Avoidance Distances for Talos Targets in miles $0 \leq (\Delta x)_T, (\Delta y)_T \leq 56$ in multiples of 8
11S3 (52) (034)	$2^{-41}\ (\Delta)_G$ ↑ Binary point lies 2 places to right of register 0 0 0 1 0 | 0 0 . = 8	$(\Delta)_G \equiv (\Delta x)_G \equiv (\Delta y)_G$ = Standard Avoidance Distance for Ships with Guns Engaged in miles $0 \leq (\Delta)_G \leq 56$ in multiples of 8 $\underbrace{1x8,\ 2x8,\ 3x8,\ 4x8,\ etc}$

0 0 1 0 0 | 0 0 . = 16

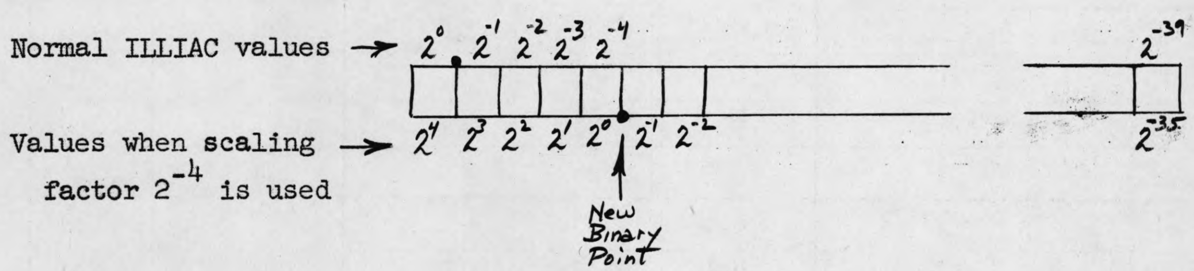
0 0 1 1 0 | 0 0 . = 24

1 0 0 0 | 0 0 . = 32

12S3 (53) (035)	2^{-39} k	k = Vector counter increment for Friend Surface Routines. If: k = 16, weapons axsignment 63 times, vectoring once, every 64 appearances k = 32, weapons assignment 31 times, vectoring once, every 32 appearances k = 64, weapons assignment 15 times, vectoring once, every 16 appearances k =128, weapons assignment 7 times, vectoring once, every 8 appearances etc.
13S3 (54) (036)	$2^{-39} Z_G$	Z_G = Vertical Gun Ranges in miles $0 \leq Z_G \leq 63$
14S3 (55) (037)	$2^{-18} R_G$	R_G = Horizontal Gun Range in miles $0 \leq R_G \leq 511$
15S3 (56) (038)	$2^{-18} R_{CPM}$	R_{CPM} = Maximum Carrier Plane Weapons Assignment Distance in miles $0 \leq R_{CPM} \leq 511$
16S3 (039)	$2^{-18} R_{CPm}$	R_{CPm} = Minimum Carrier Plane Weapons Assignment Distance in miles $0 \leq R_{CPm} \leq 511$
17S3 (58) (03K)	$2^{-4} \alpha$	α = Aircraft Pseudo-collision Course Vectoring Parameter in (1.5 seconds)/(mile) = $\frac{1}{\text{miles/1.5 seconds}}$ $0 \leq \alpha < 16$ corresponding to velocities v_f of 150 Knots to ∞ if $\alpha = \frac{1}{v_f}$, (effectively)

18S3 (59) (03S)	$2^{-18}\ R_E$	R_E = Intercept Vectoring End Distance in miles $0 \leq R_E \leq 511$

The limits given above are not imposed by the physical variability on the various quantities but by the way in which these quantities enter into the program. In all cases the limits given will embrace the possible ranges over which the respective quantities can vary.



Appendix IV

SEMI-SNYDS to DEGREES

In output messages from ILLIAC to various controlled objects, angles are expressed in a special unit called the semi-snyd.
(1 semi-snyd = $\frac{1}{256}$ of a circle = 1.406°). For the convenience of control personnel the following short table of sexadecimal-semi-snyds-to-degrees is presented.

Semi-Snyds (Sexa)	Degrees (DEC)	COS Θ	SIN Θ	Semi-Snyds (Sexa)	Degrees (DEC)	COS Θ	SIN Θ
01	001	1.000	.018	31	069	.358	.934
03	004	.998	.070	33	072	.309	.951
05	007	.993	.122	35	075	.259	.966
07	010	.985	.174	37	077	.225	.974
09	013	.974	.225	39	080	.174	.985
0S	015	.966	.259	3S	083	.122	.993
0J	018	.951	.309	3J	086	.070	.998
0L	021	.934	.358	3L	089	.018	1.000
11	024	.914	.407	41	091	.018	1.000
13	027	.891	.454	43	094	.070	.998
15	030	.866	.500	45	097	.122	.993
17	032	.848	.530	47	100	.174	.985
19	035	.819	.574	49	103	.225	.974
1S	038	.788	.616	4S	105	.259	.966
1J	041	.755	.656	4J	108	.309	.951
1L	044	.719	.695	4L	111	.358	.934
21	046	.695	.719	51	114	.407	.914
23	049	.656	.755	53	117	.454	.891
25	052	.616	.788	55	120	.500	.866
27	055	.574	.819	57	122	.530	.848
29	058	.530	.848	59	125	.574	.819
2S	060	.500	.866	5S	128	.616	.788
2J	063	.454	.891	5J	131	.656	.755
2L	066	.407	.914	5L	134	.695	.719

Appendix IV
Continued

Semi-Snyds (Sexa)	Degrees (DEC)	COS Θ	SIN Θ	Semi-Snyds (Sexa)	Degrees (DEC)	COS Θ	SIN Θ
61	136	.719	.695	K1	226	.695	.719
63	139	.755	.656	K3	229	.656	.755
65	142	.788	.616	K5	232	.616	.788
67	145	.819	.574	K7	235	.574	.819
69	148	.848	.530	K9	238	.530	.848
6S	150	.866	.500	KS	240	.500	.866
6J	153	.891	.454	KJ	243	.454	.891
6L	156	.914	.407	KL	246	.407	.914
71	159	.934	.358	S1	249	.358	.934
73	162	.951	.309	S3	252	.309	.951
75	165	.966	.259	S5	254	.276	.961
77	167	.974	.225	S7	257	.225	.974
79	170	.985	.174	S9	260	.174	.985
7S	173	.993	.122	SS	263	.122	.993
7J	176	.998	.070	SJ	266	.070	.998
7L	179	1.000	.018	SL	269	.018	1.000
81	181	1.000	.018	N1	271	.018	1.000
83	184	.998	.070	N3	274	.070	.998
85	187	.993	.122	N5	277	.122	.993
87	190	.985	.174	N7	280	.174	.985
89	193	.974	.225	N9	283	.225	.974
8S	195	.966	.259	NS	285	.259	.966
8J	198	.951	.309	NJ	288	.309	.951
8L	201	.934	.358	NL	291	.358	.934
91	204	.914	.407	J1	294	.407	.914
93	207	.891	.454	J3	297	.454	.891
95	209	.875	.485	J5	299	.485	.875
97	212	.848	.530	J7	302	.530	.848
99	215	.819	.574	J9	305	.574	.819
9S	218	.788	.616	JS	308	.616	.788
9J	221	.755	.656	JJ	311	.656	.755
9L	224	.719	.695	JL	314	.695	.719

Appendix IV
Continued

Semi-Snyds (Sexa)	Degrees (DEC)	COS Θ	Sin Θ	Semi-Snyds (Sexa)	Degrees (DEC)	COS Θ	Sin Θ
F1	316	.719	.695	L1	339	.934	.358
F3	319	.755	.656	L3	342	.951	.309
F5	322	.788	.616	L5	344	.961	.276
F7	325	.819	.574	L7	347	.974	.225
F9	328	.848	.530	L9	350	.985	.174
FS	330	.866	.500	LS	353	.993	.122
FJ	333	.891	.454	LJ	356	.998	.070
FL	336	.914	.407	LL	359	1.000	.018

Appendix V

Conversion Table for Sexadecimal ⟶ Decimal

To use the table for finding the decimal equivalent of a sexadecimal number, observe that the decimal numbers are assembled in a square matrix, each little box containing either a printed or implied decimal number. They read in order from left to right within each horizontal row.

The rows are defined by pairs of sexadecimal characters found outside each row to the left or right, while the columns are defined by single sexadecimal digits found above or below and outside the matrix.

For conversion of numbers, the whole chart should be considered as split into two charts by the heavy black vertical centerline, and for any one conversion only one-half of the chart is considered. To find the decimal equivalent of ON2, notice that the first two digits (ON) of (ON2) are in the left hand outside column; this defines the row in which the decimal equivalent will be found. Next, look for the least significant digit (2) of (ON2) in the left half of the top or bottom outside row. This defines the column. Notice that row (ON) intersects left hand column (2) at decimal box (195) which is the answer required.

	0	1	2	3	4	5	6	7	8	9	K	S	N	J	F	L	0	1	2	3	4	5	6	7	8	9	K	S	N	J	F	L	
00	0					5					10					15					20					25					30		01
02				35					40					45					50					55					60				03
04		65					70					75					80					85					90					95	05
06					100					105					110					115					120					125			07
08			130					135					140					145					150					155					09
0K	160					165					170					175					180					185					190		0S
0N				195					200					205					210					215					220				0J
0F		225					230					235					240					245					250					255	0L
10					260					265					270					275					280					285			11
12			290					295					300					305					310					315					13
14	320					325					330					335					340					345					350		15
16				355					360					365					370					375					380				17
18		385					390					395					400					405					410					415	19
1K					420					425					430					435					440					445			1S
1N			450					455					460					465					470					475					1J
1F	480					485					490					495					500					505					510		1L
20				515					520					525					530					535					540				21
22		545					550					555					560					565					570					575	23
24					580					585					590					595					600					605			25
26			610					615					620					625					630					635					27
28	640					645					650					655					660					665					670		29
2K				675					680					685					690					695					700				2S
2N		705					710					715					720					725					730					735	2J
2F					740					745					750					755					760					765			2L
30			770					775					780					785					790					795					31
32	800					805					810					815					820					825					830		33
34				835					840					845					850					855					860				35
36		865					870					875					880					885					890					895	37
38					900					905					910					915					920					925			39
3K			930					935					940					945					950					955					3S
3N	960					965					970					975					980					985					990		3J
3F				995					1000					1005					1010					1015					1020				3L
	0	1	2	3	4	5	6	7	8	9	K	S	N	J	F	L	0	1	2	3	4	5	6	7	8	9	K	S	N	J	F	L	

SEXIDECIMAL TO DECIMAL CHART

Appendix VI

ILLIAC Outputs to the Discrete Address Command Link

The aspect of the information sent ("Broadcast") by the control computer to the various operational objects is shown below. The discrete address receiver corresponding to the assigned track number (ATN) of the operational object concerned will respond and display the message following the ATN. The message type digit (0 = A-type, 1 = B-type will also be displayed). Cornfield personnel should remember to give all CAP a Z = 3 in order to allow them to receive messages (peculiarity of DAR's). Also avoid a Gate of L or 0 for Carrier; this avoids confusion between STEER and Avoidee messages since R is not received by our DAR's.

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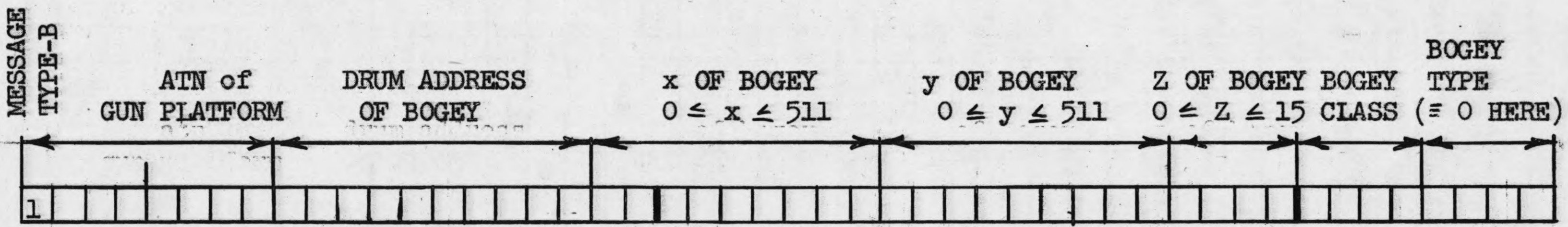
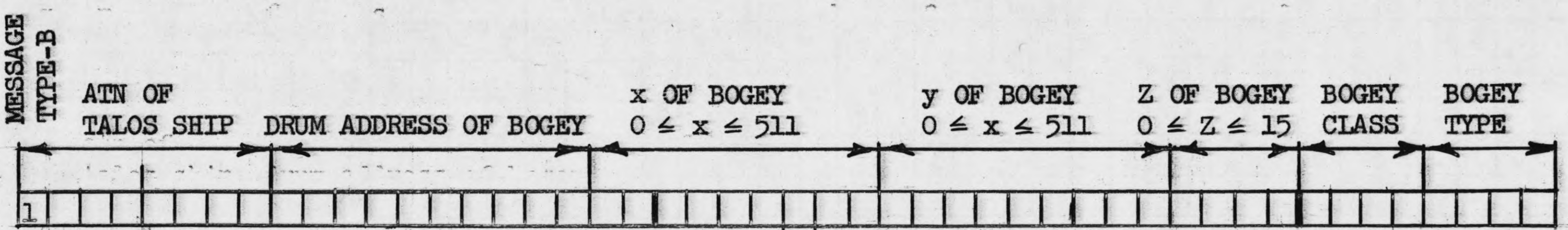


Gun Message to Friend Surface on each appearance of Bogey (all distances in miles)



TALOS message to Friend Surface once on TALOS weapons assignment (all distances in miles)

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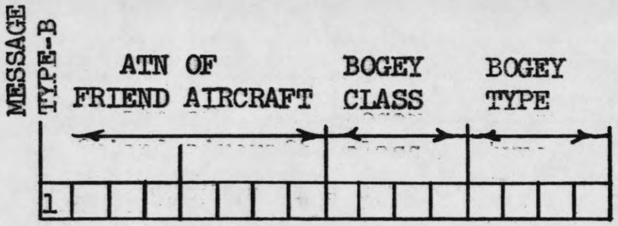
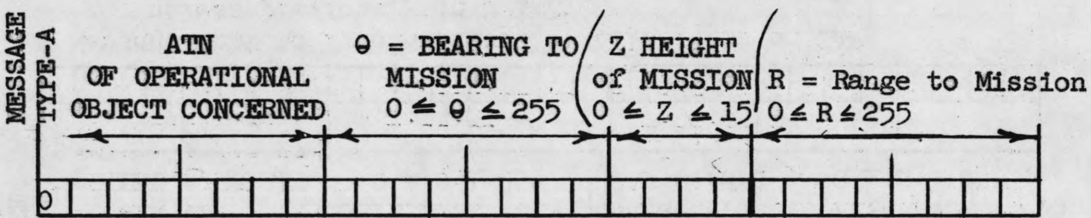
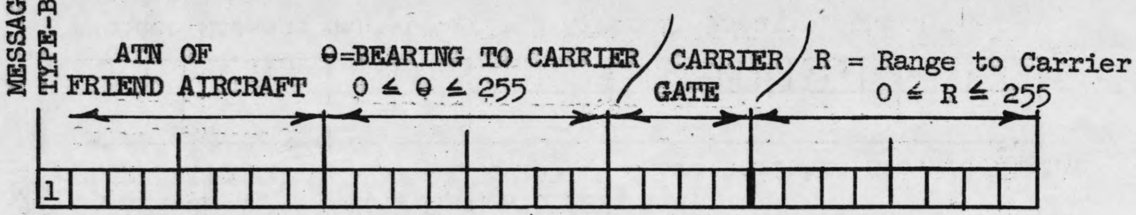


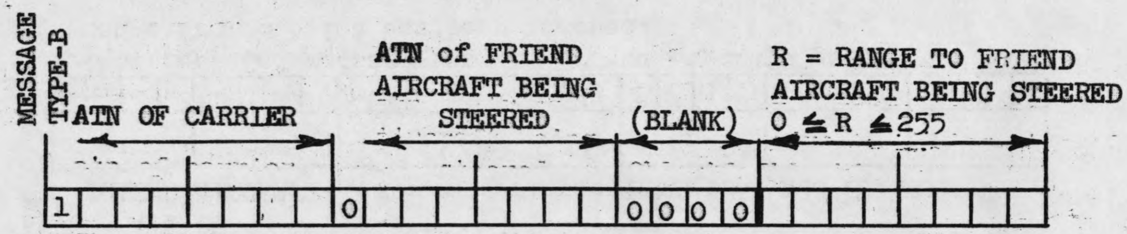
Initial Weapons Assignment to Friend Aircraft
(either airborne or on carrier deck)



Vector Message to: { Friend Surface on Vector
Carrier on Vector
Friend Aircraft on Intercept Mission



Steer Message to Friend Aircraft



Steer Message to the Carrier toward which a Friend Aircraft
is being vectored

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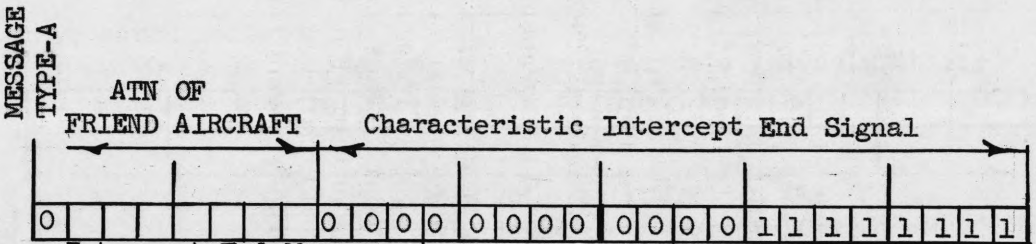
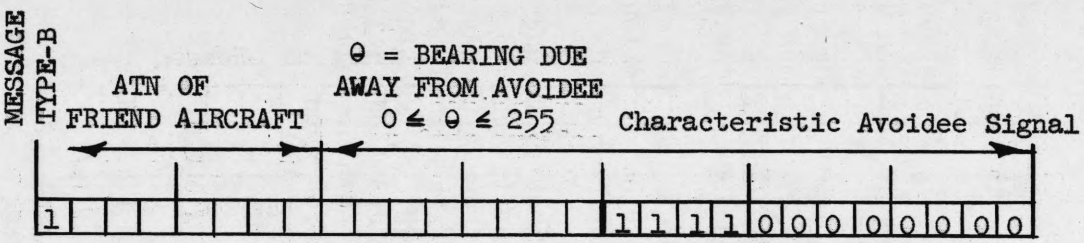
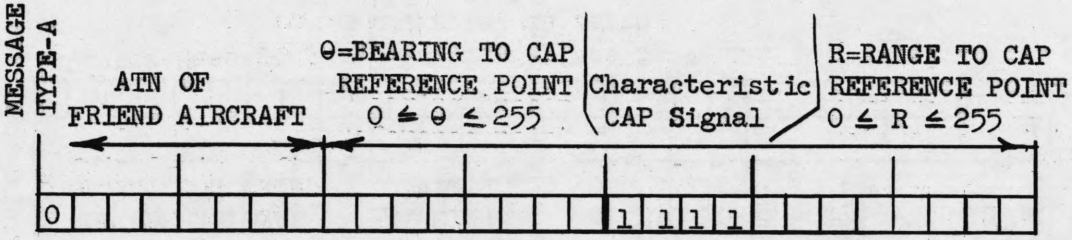


Intercept End Message sent to Friend Aircraft when a certain range from mission has been reached.



Avoidee Message sent to Friend Aircraft when it enters the avoidance area.



Message sent to Friend Aircraft while it is on CAP unless previously on STEER

In the above, ranges(R) and heights (Z) are in miles. Bearing angles (Θ) are in 256th's of a circle.

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Appendix VII

Manual Intervention into the Control Program

Part A. Summary of the Standard Intervention Modes.

Intervention Mode Selector Switch I	"Number of Digits to be Read" Switch	Action
0	-	None--Reserved to mean "No Intervention"
1	1	Turn Threat Evaluation ON
2	1	Turn Threat Evaluation OFF
3	1	Turn Weapons Assignment ON
4	1	Turn Weapons Assignment OFF
5	1	Turn Intercept Vectoring ON
6	1	Turn Intercept Vectoring OFF
7	1	Turn Vector Broadcasting ON or OFF
8	14	Read a word and an address from the Intervention Rack. Plant the word at the address in the ILLIAC Memory. See illustrative examples in Part B and Part C below

9	1	
K = 10	1	
S = 11	1	ILLIAC WILL STOP.
N = 12	1	START ILLIAC AGAIN
J = 13	1	BY ACTUATING THE ILLIAC "BLACK SWITCH"
F = 14	1	
L = 15	1	

Part B. Special Alterations of the Control Program using Intervention Mode 8 (see Part A above) (all numbers are expressed sexadecimally)

1- The program can be set to ignore all members of a given class (whether or not the members of the class are marked "ILLIAC" or "MANUAL" via the status digit S_{10}.)

Class	To Ignore the Class		To Return to Normally Processing the Class	
	Address	Word	Address	Word
0000 UN A/C	04N	2607F 00000	04N	3606F260S4
0001 UN SUR	04J	2607F 00000	04J	L30032607J
0010 UN SUB	04F	2607F 00000	04F	L30032607J
0011 AVOIDEE	04L	2607F 00000	04L	360NN220NN
0100 FOE A/C	050	2607F 00000	050	36073260S4
0101 FOE SUR	051	2607F 00000	051	L30032607J
0110 FOE SUB	052	2607F 00000	052	L30032607J
0111 STRIKEE	053	2607F 00000	053	3610F26118
1000 PF A/C	054	2607F 00000	054	36078260S4
1001 PF SUR	055	2607F 00000	055	L30032607J
1010 CARRIER	056	2607F 00000	056	4000026225

1100 FR A/C	057	2607F 00000	057	4000026082
1100 FR A/C	058	2607F 00000	058	361J8261KJ
1101 FR SUR	059	2607F 00000	059	4000026167
1110 FR SUB	05K	2607F 00000	05K	410002616K
1111 FR OTHER	05S	2607F 00000	05S	3607F26080

2- The program can be altered so as to ignore all clear picture data, but to recognize a subsequent intervention. Thus the computer can be put into a "stopped" stand-by condition and released at will in a manner similar to Intervention Modes 9, K, S, N, J, F, L. Using these modes the release is obtained by actuating a switch ("Black Switch") on the remotely located ILLIAC; using the following the release is obtained at the Intervention Rack:

To Place ILLIAC in stand-by condition:

Address: 042

Word: 2607F 00000

To Release ILLIAC:

Address: 042

Word: 81008 40003

3- The program can be altered so that no attempt is made to vector Friend Aircraft away from Avoidees. No Avoidee Vectors will be sent to the Friend Aircraft.

To neglect presence of Avoidees:

Address: 1J9

Word: 261FS 00000

To take Avoidees into account:

Address: 1J9

Word: L5258 421F0

4- The program can be altered so as to neglect any one of the four possible weapon types provided by the system. Then no assignment will ever be made to a weapon of this type.

Type of Weapon	To Ignore the Weapon		To Use the Weapon	
	Address	Word	Address	Word
Planes in the Air	20J	2621K00000	20J	L51F84017S
Planes on the deck	242	2224800000	242	L5011L0038
Talos	17F	F027636194	17F	F0276361K3
Guns	183	2219700000	183	L5016L0036

Part C. Insertion of Parameters and Data into the ILLIAC Memory Storage Banks using Intervention Mode 8 (see Part A above) (All numbers are expressed sexadecimally)

1- The Control Parameters stored in the Control Parameter Bank at S3 may be changed one by one by executing Intervention Mode 8. The appropriate 3 sexadecimal digit address for each parameter is given in the Control Parameter Table of Appendix III. The 10 sexadecimal digit word expressing the altered parameter must be constructed in accordance with the definitions given there.

2- Removal of an Avoidee from the Avoidee Banks. This operation is normally carried out via a manual input to TASCIN. In one possible case the Avoidee must be manually removed from the ILLIAC Avoidee Storage Banks. If a Bogey is assigned to TALOS, its track becomes an Avoidee Track (class digits 0011) and it is also inserted into the Avoidee Banks. If the control personnel wish to abort this assignment, a manual input to TASCIN must be used to change the appropriate Avoidee's class digits back to the proper Bogey class. Any other necessary change in the status digits should also be made (see Appendix II) (e.g. a manual assignment made, although ILLIAC can be allowed to try for a second assignment). If this process is carried out on a TALOS Avoidee ($S_1 = 1$, $S_2 = 1$), <u>whose Avoidee Number A_i (in the ATN digits) lies between 1 and 6</u>, a manual intervention must be used to remove the Avoidee from the Avoidee Banks:

Address: $2NS + A_i$

Word: LLLLL LLLLL

3- Any general change can be made in the Banks 1 and 2 Words of any operational object, if it be desired to change the operational characteristics of the object with the ATN corresponding thereto.

Mission Bank 1 Access:

Address: 300 + ATN

Word: $x_1\ x_2\ x_3\ x_4\ x_5 \quad x_6\ x_7\ x_8\ x_9\ x_{10}$

Mission Bank 2 Access:

Address: 380 + ATN

Word: $x_1\ x_2\ x_3\ x_4\ x_5 \quad x_6\ x_7\ x_8\ x_9\ x_{10}$

The sexadecimal digits x_i must be chosen to achieve the desired ends in the light of the definitions of them for the various types of operational objects given in the body of the report. Specific cases will be given below. It should be noted that the coordinates of a mission point which may be stored in Banks 1 and 2 and which are not known by the operator may be destroyed in these interventions. This is not serious since these coordinates will be automatically restored to the Banks 1 and 2 by the control program on the next appearance of the mission on the clear picture.

4- Removal of "on-vector" mark for Friend Surface, Friend Subsurface, Surface Friend Other, Carrier, Surface Protectee. Such objects will be initially set to "do-not-vector". A subsequent assignment will <u>automatically</u> place them "on-vector". Only if it is subsequently desired to place them on "do-not-vector" need this intervention into Mission Bank 2 be executed:

Address: 380 + ATN

Word: 00000 00300

5- To change arament type of a Friend Surface, Carrier, or Surface Protectee execute intervention into Mission Bank 1:

Address: 300 + ATN

Word: 00000 00000 x_{10}

where in binary: x_{10} = 0000 Unarmed

x_{10} = 0001 Guns

x_{10} = 0010, 0011 } TALOS

Notes: To set x_{10} = 0000 is the only way to keep a Surface Protectee from being tested for Gun Weapons Assignment.

The armament settings above on Carrier will have the effects discussed in Chapter II, Section H.

6- To insert additional Carrier Plane ATN's into the Carrier Plane Bank.

Address: 2F3 + (ATN of Carrier)

Word: $x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}$

where: $x_1\ x_2$ = ATN of Carrier Plane 1st to be launched

$x_3\ x_4$ = ATN of Carrier Plane 2nd to be launched

$x_5\ x_6$ = ATN of Carrier Plane 3rd to be launched

$x_7\ x_8$ = ATN of Carrier Plane 4th to be launched

$x_9\ x_{10}$ = ATN of Carrier Plane 5th to be launched

7- To remove a Protectee or a Protectee Carrier from the ILLIAC Protectee Banks if it is changed in TASC to a non-Protectee object:

Address: 2LS + (ATN of Protectee)

Word: 80000 00000

8- To put an Aircraft Protectee on "steer":

Address: 300 + (ATN of Protectee)

Word: 00000 LL x_8 x_9 x_{10}

where in binary : $x_8\ x_9\ x_{10} = 00\ a_1\ a_2\ a_3\ a_4\ a_5\ a_6\ a_7\ a_8\ a_9\ a_{10}$

and where $a_1\ a_2 \ldots a_{10}$ express the decimal number

747 + (ATN of Carrier to which steered)

in binary notation.

9- To place Friend Aircraft or Aircraft Protectee on CARRIER CAP about home carrier:

Address: 300 + ATN

Word: 00000 L000x_{10}

where: x_{10} = ATN of home carrier.

Note: Only necessary after object has previously been on "steer", or if object is being changed to CARRIER CAP.

10- To place Friend Aircraft or Aircraft Protectee on GEOREF CAP (two interventions necessary):

Address: 300 + ATN

Word: 00 x_3 x_4 x_5 0000 x_{10}

<u>and</u>:

Address: 380 + ATN

Word: 00 y_3 y_4 y_5 y_6 y_7 y_8 00

where: $x_3\ x_4\ x_5 = 00\ \underbrace{\text{vvvvvvvvv}}_{x_{GR} \text{ in miles (binary)}}\ 0$ (12 binary digits)

x_{10} = ATN of home carrier

$y_3\ y_4\ y_5 = 00\ \underbrace{\text{vvvvvvvvv}}_{Y_{GR} \text{ in miles (binary)}}\ 0$

$y_6\ y_7\ y_8$ = vvvvvvvvvv 00

BP

g fuel units consumed/mile (binary)

Note: This intervention is necessary for Friend Aircraft only if it has previously been on an intercept mission. It is necessary for both Friend Aircraft and Aircraft Protectee if they are being changed from CARRIER to GEOREF CAP.

11- Georef coordinates are inserted into the Mission Banks 1 and 2 of any Aircraft Friend Other (or any other operational object for which this may be desired) by using the positional portions of the rules given in step 10 above.

12- To insert ATN of home carrier into a Friend Aircraft's Mission Bank 1 word:

Address: 300 + (ATN of Friend Aircraft)

Word: — — — — — — — — — x_{10}

where: x_{10} = ATN of home carrier and where the other nine digits are to be consistent with the rules pertaining to the information carried in these digits.

13- To prevent any Friend Aircraft from ever getting a weapons assign, set g = fuel units consumed/mile in Mission Bank 2 word to the maximum possible value, g = 3 + 255/256 fuel units consumed/mile:

Address: 380 + ATN

Word: 00000 LLN00

14- In case a large number of the above described words need to be inserted into ILLIAC at one time during operation, the word-by-word insertion via Intervention Mode 8 would be inefficient and time consuming. ILLIAC should be stopped using one of Intervention Modes 9-L. The ILLIAC input should be switched to a tape reader and a miniature bootstrap inserted as explained in Section M of R-74 using the white "Execute Switch" and the "Counter Reset" and "R_3 Set" buttons. The words to be inserted should be placed on the tape following the Miniature Bootstrap and should consist of a list of 3 sexadecimal digit insertion addresses each followed by the 10 sexadecimal digit word to be inserted. This tape should be terminated by

000 26040 00000 000

which will automatically restart ILLIAC at the proper place in the Main Read Routine.

000 24040 00000 000

can be used, in which case ILLIAC will restart only after the "Black Switch" is actuated.

ASSIGNMENT OF MEANINGS FOR

Symbol	ATN assignment			RMB NO.	I_{11}	I_{10}	I_9	I_8	I_{21}	I_7	I_6	I_5	I_4	I_3	I_2	I_1
				JSL NO.	1	2	3	4	5	6	7	8	9	10	11	12
				SNYDERS NO.	11	12	13	14	10	—	—	—	—	—	—	—
					CLASS DIGITS				ILLIAC OR MANUAL DESIGNATOR (0= ILLIAC, 1= MANUAL)	T	THREAT NO.					
U ✈	ATN OF FRIENDLY OBJECT BEING SENT IN PURSUIT	UNIDENTIFIED	AIR		0	0	0	0		A	ATN					
U □		UNIDENTIFIED	SURF		0	0	0	1		A	ATN					
U ■		UNIDENTIFIED	SUBSURF		0	0	1	0		A	ATN					
S		AVOIDEE			0	0	1	1		N	ATN					
										T	THREAT NO.					
H ✈		HOSTILE	AIR		0	1	0	0		A	ATN					
H □		HOSTILE	SURF		0	1	0	1		A	ATN					
H ■		HOSTILE	SUBSURF		0	1	1	0		A	ATN					
S ×		STRIKEE			0	1	1	1		A	ATN			0-127 / 0, 1, 2, +3		
										T	THREAT NO.					
P ✈		PROBABLE FRIEND	AIR		1	0	0	0		A	ATN					
P □		PROBABLE FRIEND	SURF		1	0	0	1		A	ATN					
S +	0-127 ASSIGNED	CARRIER			1	0	1	0		N	ATN			0 Will be Ignored		[1-8 Only]
S ●		PROTECTEE			1	0	1	1		N	ATN			0 Will be Ignored		[1-4 Only]
F ✈		FRIENDLY	AIR		1	1	0	0		N	ATN					
F □		FRIENDLY	SURF		1	1	0	1		N	ATN					
F ■		FRIENDLY	SUBSURF		1	1	1	0		N	ATN					
S ◥	0-127	OTHER (IGNOREE)			1	1	1	1		N	ATN			Ignored if $S_1=0$ Must not duplicate any ATN if $S_1=1$		

I_{20}	I_{19}	I_{18}	I_{17}	I_{16}	I_{15}	I_{14}	I_{13}	I_{12}			NOTES
13	14	15	16	17	18	19	20	21	22	23	
1	2	3	4	5	6	7	8	9	—	—	
0 / 1	SIZE	G=1 / P=0					TYPE 0-7		K	L	
							TYPE		K	L	
							TYPE		K	L	
0=NO PRIOR. / 1=PRI-ORITY		SET TO 1 TO ERASE		Δx			Δy		K	L	Use F-ATN=8 For Manual Non-priority Use P-ATN=64 For Manual TALOS WA
0 / 1	SIZE	G=1 / P=0					TYPE		K	L	
							TYPE		K	L	
							TYPE		K	L	
0 / 1	0 / 1			ATN NO. 2							SINGLE / DOUBLE STRIKE TARGET FRAME END MARK
0 / 1	SIZE	G=1 / P=0					TYPE		K	L	
							TYPE		K	L	
0 ACCEPT / 1 NOT ACPT	0 NOT PROT. / 1 ALSO PROT		GATE			0 NO GUNS / 1 GUNS	0 NO PLANE / 1 PLANE		K	L	
0 Georef / 1 Object	0=a/c 1=surf						FREE		K	L	
00 CAP 01 INTERCEPT 10 STEER 11 STEER CRIT			FUEL				TYPE		K	L	
1 Avail. / 0 Not Avail.	0 Not / 1 Avoid	Set to 1 to Erase Avoidee	AVOIDEE NO.				TYPE		K	L	Use Avoidee No. 7 For Manual
							TYPE		K	L	
0 Ignore / 1 Process	0=AC 1=SURF						TYPE		K	L	Illiac ignores this class if S_1=0 Will vector if S_1=1

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